FLORIDA GEOLOGICAL SURVEY

FIFTEENTH ANNUAL REPORT

FLORIDA STATE GEOLOGICAL SURVEY

HERMAN GUNTER, STATE GEOLOGIST

FIFTEENTH ANNUAL REPORT
1922-1923

ADMINISTRATIVE REPORT
MINERAL INDUSTRIES
PALEONTOLOGY OF NORTHEASTERN FLORIDA
CLAYS OF FLORIDA

PUBLISHED FOR
THE STATE GEOLOGICAL SURVEY
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LETTER OF TRANSMITTAL

To His Excellency, Hon. Cary A. Hardee, Governor of Florida:

Sir:—I have the honor to submit herewith the Fifteenth Annual Report of the State Geologist. In addition to the Administrative Report, which contains a statement of the expenditures of the Survey from January 1, 1922, to July 1, 1923, and a statistical summary of the mineral industries for the years 1921 and 1922, it contains a paper on the paleontology of northeastern Florida by Wendell C. Mansfield of the United States Geological Survey, and a report on the clays of Florida by Olin G. Bell of Cornell University.

In the preparation of the report on clays most of the counties were visited and from many of them samples were obtained. Owing to limited time for field work and to the finances of the Survey, it was not possible to collect as many samples as we would have liked, or to make chemical analyses. The investigation thus far conducted, however, shows that the State has large quantities of clay suitable for the manufacture of common building brick, drain tile, building tile and earthenware. The very plastic ball clays are admirably adapted to the manufacture of high-grade porcelain when mixed with less plastic clays.

With the decreased output of lumber in Florida and the consequent rise in price, there comes an increasing demand for the more durable building materials. Clay must enter more largely into the manufacture of brick and building tile in this State and it is not improbable that it will be used in the manufacture of cement. Economic and industrial conditions point to a constant development of the clay industry.

It is hoped that this report may be the means of stimulating the clay industries already established and promote the bringing of others to the State.

The uniformly cordial interest that you have shown toward the work of this Department is appreciated.

Very respectfully,

HERMAN GUNTER,
State Geologist.

November, 1923.

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ADMINISTRATIVE REPORT.

HERMAN GUNTER, STATE GEOLOGIST.

INTRODUCTION.

The Florida State Geological Survey was created by an Act of the Legislature of 1907. The Act provided for the appointment of a State Geologist, and specified his duties; it detailed the object of the Survey, and appropriated $7,500 a year for its maintenance.

The Act establishing the Survey has in no wise been changed until by the Legislature of 1923. During the session of 1921 an Act was passed creating a Budget Commission for the State of Florida. This Act made it the duty of each of the State Departments to submit an estimate of the amount needed for the two-year period beginning July 1st, 1923. The appropriation for the maintenance of the Survey as effected by the Appropriation Bill was increased from $7,500 annually to $10,345.

Since the publication of the Fourteenth Annual report the Geological Survey's force has been, in addition to the State Geologist, Mr. M. K. Cooke, Assistant, whose services terminated November 1, 1922. Mr. Olin G. Bell was employed as special or temporary assistant during the three-month summer period of 1922, which time was spent in the field preparatory to the report on the clays of Florida comprised in this volume. Mr. Strauss L. Lloyd also rendered a few day's special service to the field party while investigating the clays of Hernando and Citrus counties. Sam E. Cobb, Jr., was employed temporarily and rendered assistance in cataloging specimens and other general office work. Mrs. Mabel Lee rendered half-time service as stenographer from September, 1922, to March, 1923.

NEW SURVEY QUARTERS

Upon completion of the addition to the Capitol Building the Survey was provided space on the south side of the lower floor of the west extension. In its new location the Survey has one room 27 by 33 feet, which is used for displaying geological material and for the library. Connected with this are two rooms, the one used as office of the State Geologist, while the other is for the Secretary. Additional room is needed, particularly for the purpose of mailing and for the purpose of storage. The exhibition room is likewise too small, since there is scarcely any space for additional exhibition cases.

WORK OF THE SURVEY

Administrative:—The work of the State Geologist has consisted of making plans for proposed investigations, correspondence and conferences relating to their carrying out, the obtaining of bids for the purchase of supplies and of printing reports, the care of the Survey property, the supervision of work in progress and of printing and distribution of reports, and in attendance to the usual correspondence of the office.

During the years the Survey has been organized no special appropriation for the employment of a Secretary-stenographer was made. As a consequence during much of the time no regular stenographic service, however much needed, has been rendered the Survey. By provision of the Legislature of 1923, effective July 1, 1923, the Survey will have the services of a full-time stenographer.

Bureau of Information:—A large part of the time of the State Geologist is taken up in answering personal and written inquiries of all kinds regarding the mineral and natural resources of the State. These come from private landowners, prospective citizens, investors, railways, cities, commercial bodies, teachers, students, and in fact, from all classes of people, both citizens and non-residents. This work is considered an important function of the Survey and replies are made as full and explicit as possible. When necessary, printed reports are sent in addition. The Survey has embraced the opportunities for building up new enterprises and to get before the public data relative to the State's resources.

Preparation of Reports:—Upon completion of the field work, a large amount of office and laboratory work is necessary in order to get a report upon a given subject in shape for the press. In the case of the present report on the clays, much detailed laboratory work was necessary in order to get the results of the physical and burning tests of the several samples. Chemical analyses are frequently made and maps and drawings are prepared to show the location of the deposits, and the arrangement or order of the manuscript must be considered, as well as the final proof reading while going through the press. The illustrations of the reports, too, are selected with care and aid in visualizing the occurrence and preparation of the natural product for the market.

Publications of the Survey:—The results of the investigations by the Survey are issued in the form of annual reports. These reports are issued as a whole volume and also the papers making up the volume are bound separately. By this method anyone interested only in some particular subject treated in the whole report can obtain it by getting only the separate paper. These reports are distributed free to all residents and to all boards of trade or corresponding bodies in the State, and to the libraries of the State and to certain exchange libraries of the United States and foreign countries. Requests for publications from residents of States other than Florida should be accompanied with postage. In addition to the annual reports the Survey has issued two bulletins and twelve press bulletins. A complete list of the reports so far issued by the Survey may be had by writing the State Geologist, Tallahassee.

PLANS OF THE SURVEY

In planning for field work regard is paid to the following: The request for information along any given line and information obtained about resources that apparently offer opportunities of development. Thus the present report on the clays, it is thought, is very timely. It is planned to follow this with a report on the limestones and marls. Upon the completion of this, information would be in hand relative to the cement resource possibilities of the State.

Peat:—A preliminary report on the peat deposits of the State was published by the Survey in 1910, but the edition is now exhausted. Requests are regularly being received for information, particularly as to the fuel value of our peat bogs. Investigation and report upon the peat deposits of the State with particular reference to their fuel value should be made. There are known to be beds of peat in Florida that might prove of large value to local industries in this respect. Their location, extent and value should be determined.

Geography of Southern Florida:—The report on the geography of Central Florida, in the Thirteenth Annual Report, has supplied just the information many persons have wanted. Work is now in progress on a similar report for Southern Florida.

EXPENDITURES OF THE GEOLOGICAL SURVEY FROM JANUARY 1, 1922, TO JULY 1, 1923

The following itemized list shows the expenditures of the Survey from January 1, 1922, to July 1, 1923. The total annual appropriation during this period was $7,500. With the exception of the salary of the State Geologist, which amount is fixed by statute, all accounts are approved by the Governor and are paid only by warrant drawn upon the State Treasurer by the Comptroller, no part of the fund being handled direct by the State Geologist. All original bills and itemized expense accounts are on file in the office of the Comptroller, duplicate copies being retained in the office of the State Geologist.

LIST OF WARRANTS ISSUED FROM JANUARY 1, 1922, TO JULY 1, 1923.

JANUARY, 1922.	
M. K. Cooke, assistant, salary	$ 125.00
M. K. Cooke, assistant, expenses	21.55
M. K. Cooke, assistant, auto mileage	55.52
Fred Collins, janitor services	10.00
George B. Perkins, rent for January	41.66
Southern Telephone & Construction Co., rent	3.50
Yeager-Rhodes Hardware Co., supplies	2.65
Economic Geology Publishing Co.	4.00
American Railway Express Co.	1.15
FEBRUARY, 1922.	
Herman Gunter, State Geologist, expenses	$ 85.49
M. K. Cooke, assistant, salary	125.00
M. K. Cooke, assistant, expenses	18.75
M. K. Cooke, assistant, auto mileage	48.80
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
American Railway Express Co.	2.39
MARCH, 1922.	
Herman Gunter, State Geologist, salary for quarter ending March 31, 1922	$ 625.00
M. K. Cooke, assistant, salary	125.00
E. H. Sellards, field expenses	94.00
Sam Cobb, services February and March	14.25
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
American Railway Express Co.	1.45
W. H. May, postmaster, stamps and post-office box rent	21.50
W. C. Dixon, drayage	1.75
T. J. Appleyard, letter heads	4.50
Yeager-Rhodes, Hardware Co., supplies	1.65
H. & W. B. Drew Co., supplies	2.36
Fielder & Allen Co., supplies	14.00
D. C. Heath & Co.	12.00

APRIL, 1922.

M. K. Cooke, assistant, salary	$ 125.00
M. K. Cooke, assistant, expenses	25.69
M. K. Cooke, assistant, auto mileage	72.00
Sam Cobb, services	8.50
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
American Railway Express Co.	3.71
Ellis, Curtis & Kooker, maps of Florida	1.67
Wrigley Engraving & Electrotype Co.	16.65

MAY, 1922.

M. K. Cooke, assistant, salary	$ 125.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
W. H. May, postmaster, stamps	50.00
Grant Furniture Co., letter folders	2.50
Wrigley Photo Engraving Corp.	4.75
Commercial Fertilizer, subscription	2.00
University of Chicago Press	3.60
McGraw-Hill Book Co.	6.00
Southern Telephone & Construction Co.	3.50
American Railway Express Co.	.93

JUNE, 1922.

Herman Gunter, State Geologist, salary for quarter ending June 31, 1922	$ 625.00
Herman Gunter, State Geologist, expenses	28.73
M. K. Cooke, assistant, salary	125.00
M. K. Cooke, assistant, expenses	68.61
M. K. Cooke, assistant, auto mileage	121.00
Olin G. Bell, assistant, salary June 13-30	120.00
Olin G. Bell, assistant, expenses	86.72
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
Western Union Telegraph Co.	2.28
Alford Brothers, camp supplies	3.50
T. J. Appleyard, letter heads and envelopes	15.50
Milton A. Smith, 2,000 report cards	9.00
Brock-Sharp Machinery Co., field equipment	12.44
Smedley & Rogers Hardware Co., field equipment	5.00
H. & W. B. Drew Co., supplies	9.43

JULY, 1922.

M. K. Cooke, assistant, salary	$ 125.00
M. K. Cooke, assistant, expenses	94.20
M. K. Cooke, assistant, auto mileage	196.80
Olin G. Bell, assistant, salary	200.00
Olin G. Bell, assistant, expenses	147.11
L. B. Marshall, copying mineral tabulations	15.25
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50

City Transfer Co., Tampa, packing, shipping clay samples	$ 8.00
American Railway Express Co.	4.29
W. H. May, postmaster, stamps	25.00
W. C. Dixon, freight and drayage	1.47
The Record Co., Columbia envelopes	30.75
Millhiser Bag Co., cloth bags	35.97

AUGUST, 1922.

M. K. Cooke, assistant, salary	$ 125.00
M. K. Cooke, assistant, expenses	107.85
M. K. Cooke, assistant, auto mileage	219.50
Olin G. Bell, assistant, salary	200.00
Olin G. Bell, assistant, expenses	122.69
Strauss L. Lloyd, services	23.00
Mrs. Lila B. Robertson, special services	30.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
American Railway Express Co.	30.57
Yeager-Rhodes Hardware Co., supplies	1.85
W. C. Dixon, freight and drayage	19.91
Kite Transfer, freight and drayage clay samples	18.92
The Record Co.	15.00

SEPTEMBER, 1922.

Herman Gunter, State Geologist, salary for quarter ending September 30, 1922	$ 625.00
Herman Gunter, State Geologist, expenses	12.20
M. K. Cooke, assistant, salary	125.00
M. K. Cooke, assistant, expenses	6.25
M. K. Cooke, assistant, auto mileage	30.14
Olin G. Bell, assistant, salary, September 1-12, inclusive	80.00
Olin G. Bell, assistant, expenses	28.23
Mrs. Mabel Lee, stenographic services	27.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
Hill's Transfer, drayage	2.00
Charles Williams, supplies	1.75
American Railway Express Co.	2.46
W. H. May, postmaster	31.50
Kite Transfer, freight and drayage	11.00
H. & W. B. Drew Co., supplies	1.84
Ivan Allen-Marshall Co., supplies	12.40
The Record Co., printing	836.75
The Crystal Pharmacy, photo supplies	6.74

OCTOBER, 1922.

Herman Gunter, State Geologist, expenses	$ 175.06
M. K. Cooke, assistant, salary	125.00
Mrs. Mabel Lee, stenographic services	30.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50

W. C. Dixon, freight and drayage	$ 8.50
A. Hoen & Co., geologic map	640.00
McGraw-Hill Book Co., Inc., book	3.00
Leslie Tyler, freight and drayage	32.12
W. H. May, postmaster	25.00
H. R. Kaufman, typewriter repair and supplies	1.75
American Railway Express Co.	15.45

NOVEMBER, 1922.

Herman Gunter, State Geologist, October salary	$ 208.33
Herman Gunter, State Geologist, salary	208.33
Herman Gunter, State Geologist, expenses	32.82
Mrs. Mabel Lee, stenographic services	30.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
Grant Furniture Co., supplies	2.50
Leslie Tyler, freight and drayage	68.82
Engineering & Mining Journal-Press, subscription	4.00
John Wiley & Sons, publication	3.50
The Science Press, publication	10.00
University of Chicago Press, publication	2.10

DECEMBER, 1922.

Herman Gunter, State Geologist, salary	$ 208.34
Herman Gunter, State Geologist, expenses	102.84
Mrs. Mabel Lee, stenographic services	30.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Southern Telephone & Construction Co.	3.50
W. H. May, postmaster	26.50
T. J. Appleyard, stationery	8.75
American Railway Express Co.	3.29
American Peat Society, subscription	5.00
American Philosophical Society	2.08
The Ora Neff Co., supplies	3.86

JANUARY, 1923.

Herman Gunter, State Geologist, salary	$ 208.33
Mrs. Mabel Lee, stenographic services	40.00
Fred Collins, janitor services	10.00
George B. Perkins, office rent	41.66
Grant Furniture Co., supplies	5.25
American Railway Express Co.	2.35
Doubleday, Page & Co., publications	10.00
W. S. Brown, compass	2.11
Warren K. Moorehead, publications	9.18
Dixon's Transfer, moving office and museum supplies	61.00

FEBRUARY, 1923.

Herman Gunter, State Geologist, salary	$ 208.33
Mrs. Mabel Lee, stenographic services	40.00
Fred Collins, janitor services	10.00
Grant Furniture Co., supplies	2.50
Southern Telephone & Construction Co.	3.25
Weekly Naval Stores Review, publication	3.25
Economic Geology Publishing Co., subscription	4.00

MARCH, 1923.

Herman Gunter, State Geologist, salary	$ 208.34
Mrs. Florence M. Epperson, special stenographic services	13.00
Fred Collins, Janitor services	10.00
Southern Telephone & Construction Co., balance on April	1.00
W. H. May, postmaster	26.50
W. L. Marshall, repairs on shelving	4.00
American Railway Express Co.	6.22

APRIL, 1923.

Herman Gunter, State Geologist, salary	$ 208.34
Mrs. Florence M. Epperson, special stenographic services	7.80
Fred Collins, janitor services	10.00
Southern Telephone & Construction Co.	3.25
T. J. Appleyard, printing	18.75
Commercial Fertilizer, subscription	2.00

MAY, 1923.

Herman Gunter, State Geologist, salary	$ 208.33
Herman Gunter, State Geologist, expenses	22.15
Southern Telephone & Construction Co.	3.25
Fred Collins, janitor services	10.00
T. J. Appleyard, envelopes, stationery, etc.	72.15
W. H. May, postmaster	40.00
American Railway Express Co.	3.78
Grant Furniture Co., 6 shades	42.00
University of Chicago Press, Journal of Geology	3.60
Carnegie Institution of Washington, publication	3.50

JUNE, 1923.

Herman Gunter, State Geologist, salary	$ 208.33
Herman Gunter, State Geologist, expenses	25.72
Sam E. Cobb, Jr., services	65.00
Fred Collins, janitor services	10.00
Southern Telephone & Construction Co.	3.80
W. H. May, postmaster	51.50
State Road Department, blue printing	1.20
Underwood Typewriter Co., balance on new machine	69.10
Maurice-Joyce Engraving Co., half-tones	234.93
D. A. Dixon Co., supplies	13.40

STATISTICS ON MINERAL PRODUCTION IN FLORIDA DURING 1921 AND 1922

COLLECTED IN CO-OPERATION BETWEEN THE FLORIDA GEOLOGICAL SURVEY, THE UNITED STATES GEOLOGICAL SURVEY, AND THE U. S. CENSUS BUREAU

The total value of the minerals produced in Florida during 1921 was $12,986,699. This represents a very decided decrease in total value of production over that of 1920, the reduction being mainly accounted for in the decreased output and value of phosphate. For 1922 the total mineral production value reached $11,445,073. The continued slight decrease in the production and value of phosphate was somewhat offset by the increased production and value of all of the other mineral industries of the State.

BALL CLAY OR PLASTIC KAOLIN

This high-grade clay was discovered in Florida near Lake Eustis, Lake County,* and Mr. Lawrence C. Johnson, of the United States Geological Survey, is credited with first reporting its occurrence.† A record of the beginning of mining is contained in the Mineral Resources of the United States for the year 1893, page 614. An interesting fact in this connection is that the Edgar Plastic Kaolin Company, of Metuchen, N. J., who were among the first to mine this clay in Florida, have continued to mine through the intervening years and are heavily interested in properties in Putnam and Lake counties. Mining has been carried on continuously since the year above mentioned and the ball clay industry of Florida has continued to increase in importance.

The Florida ball clays mined at Edgar, Putnam County, and near Leesburg, Lake County, are the purest found in this country. The clay occurs intimately mixed with coarse sand and quartz pebbles, these latter forming the larger percentage of the mass. The only treatment in the process of refining is that of washing, which removes the sand and

*U. S. Geol. Surv., Min. Res. of the U. S., 1889 and 1890, p. 441, 1892.
†Ibid, Min. Res., 1891, p. 507, 1893.

pebbles. The washed clay is shipped to northern potteries where it is used in the manufacture of the higher grade of white wares. Although produced commercially in only two counties of the State, these clays are distributed through the central peninsular portion of Florida and to some extent in northern and western Florida.

The value of the output is not given separately, but is included with the total value of the mineral products of Florida. The following companies operated in 1922:

Edgar Plastic Kaolin Company, Metuchen, N. J., and Edgar, Fla.
Florida China Clay Corp., 640 N. 13th St., Easton, Pa., and Leesburg, Fla.
Lake County Clay Co., Metuchen, N. J., and Okahumpka, Fla.

BRICK, TILE AND POTTERY

The greatly increased activity in building throughout the State is reflected in the increase in production of brick and tile by the several plants operating in Florida during 1921 and 1922. The total number of common brick manufactured in Florida during the latter year, as reported by the producers to the Florida Geological Survey, was 26,296,000. Two concerns report the production of face-brick and one the manufacture of building tile. The total value of brick, tile and pottery products in 1922 is given at $207,449.

The following firms manufactured brick and tile during 1922:

Barrineau Bros., Quintette, Escambia County.
J. M. & J. C. Craber, Campville, Alachua County.
E. M. Davis, Lawrence, Gadsden County, (P. O. Ocklocknee).
Dolores Brick Co., Molino, Escambia County.
Florida Industrial School for Boys, Marianna, Jackson County.
Gamble & Stockton Co., Jacksonville, Duval County.
Glendale Brick Works, Glendale, Walton County.
G. C. and G. H. Guilford, Blountstown, Calhoun County.
W. J. Hall & Son, Chipley, Washington County.
Hull & Cowan Co., Callahan, Nassau County.
Keystone Brick Co., Whitney, Lake County.
Morris-Blumer Co., Brooksville, Hernando County.
Tallahassee Pressed Brick Co., Havana, Gadsden County.

There were two plants in Florida during 1922 that manufactured decorated vases and other pottery. These were: The Graack Pottery, Bradentown, and the Orlando Potteries, Orlando.

DIATOMACEOUS EARTH

This material, deposits of which are located in Lake County and mined several years ago near Eustis, has not been produced in Florida for several years. Renewed activity in diatomaceous earth deposits of Lake County is shown by the organization of The Florida Diatomite Company, of Clermont. Samples of this earth have been received from Mr. C. Lindley Wood, President of the company named, and from these the material is shown to be of high quality. A small sample of both the crude and the burned earth was submitted to Dr. Albert Mann, Diatomist, Carnegie Institution, Washington, and the following paragraphs are quoted by permission.*

"Your sample, when freed from organic matter, is a pure fresh-water diatom material of recent origin, practically free from any clay, sand, iron or other deleterious material. The different species of diatoms composing it vary considerably in size, contrasting thereby with such homogeneous diatom earths as those from Nevada, etc. This may be an advantage or a disadvantage according to the commercial purposes to which it is put.

"As the ratio of organic matter to diatom silica is unusually low I think it would be a profitable substance to put on the market."

FULLER'S EARTH

The demand for fuller's earth in 1922 was more active than during the year 1921. The output of this product in 1922 was second only to the output in 1920, the banner year of the fuller's earth industry in Florida. According to published statistics by the United States Geological Survey, Florida is credited with a production of 64,122 short tons, valued at $1,122,940, or an average of $17.51 a ton.† According to the same authority this was 46 per cent of the total output of this earth in the United States and 49 per cent of the total value.

The following companies reported production of fuller's earth in 1922:

Attapulgus Clay Company, Ellenton, Manatee County.
Floridin Co., Quincy and Jamieson, Gadsden County.
Fuller's Earth Company, Midway, Gadsden County.
Manatee Fuller's Earth Corporation, Ellenton, Manatee County.

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*Letter of Sept. 20, 1923.
†U. S. Geol. Surv., Min. Res., 1922, Pt. II, p. 70, 1923.

ILMENITE

Ilmenite was recovered from the beach sands of the Atlantic Coast at Mineral City, near Pablo Beach, Duval County, during 1922. Messrs. Buckman and Pritchard, Inc., who formerly operated the plant, have sold their interests to the National Lead Company of New York. The output and value of ilmenite cannot be given separately without disclosing individual production, but it is included in the total of the State.

LIMESTONE, LIME AND FLINT

The increased activity in road building in Florida has resulted in a largely increased output of limestone and crushed flint rock. The total amount of limestone, as reported by the several producers, sold in Florida during 1922 was 656,910 tons valued at $622,378. The various purposes for which this limestone was used were: road metal; railroad ballast; agricultural purposes; rock for foundations, sea walls and similar work and other miscellaneous uses. To the above total should be added the amount of lime and of crushed flint rock which brings the total production of limestone, quick-lime, hydrated lime and crushed flint rock to 824,150 tons, valued at $857,913.

The companies operating in 1922 were:

Blowers Lime and Phosphate Company, Ocala.
Brooksville Lime, Fertilizer and Crushed Rock Co., Brooksville.
Commercial Lime Company, Ocala and Reddick.
Crystal River Rock Co., Leesburg and Crystal River.
Cummer Lumber Co., Newberry and Kendrick.
Carl H. Fay, Cocoa.
Florida Hard Rock Corporation, Ocala.
Florida Lime Company, Ocala.
The Maule-Ojus Rock Company, Ojus.
Oakhurst Lime Company, Ocala.
Ocala Lime Rock Company, Ocala and Kendrick.
Ojus Rock Company, Ojus.
F. F. Smith, Volusia.
State Road Department of Florida, Tallahassee and Pineola.
A. T. Thomas Company, Ocala.
Volusia Coquina Rock Company, Volusia.

PEAT

There was only one plant that reported production of peat in Florida for 1922. The use for which this peat was sold is reported as for fuel purposes. The total production and value is included with the total for the State. The operator reporting production was Mr. Robert Ranson, St. Augustine.

PHOSPHATE

The year 1920 is the record year for the phosphate industry both in the quantity produced and in value. Following that year came one of depression which was due largely to the European situation and possibly to some extent also to the large output during 1920. The total shipment of phosphate during 1921 was 1,780,028 long tons with a total valuation of $10,431,642. This is 1,589,356 long tons less than the output for 1920 and a decrease in value of $9,032,720, or a reduction of about 45 per cent in output and of about 46 per cent in value.

The year 1922 is marked by an increase in production of both the hard rock and pebble rock varieties and with only a very small output of soft phosphate. In value, however, there was a decided reduction. The total shipments of phosphate from Florida for 1922 were 2,058,593 long tons valued at $8,347,522. This is an increase of 278,565 long tons or about 14 per cent in production but a decrease in total value of $2,084,120 or about 19 per cent.

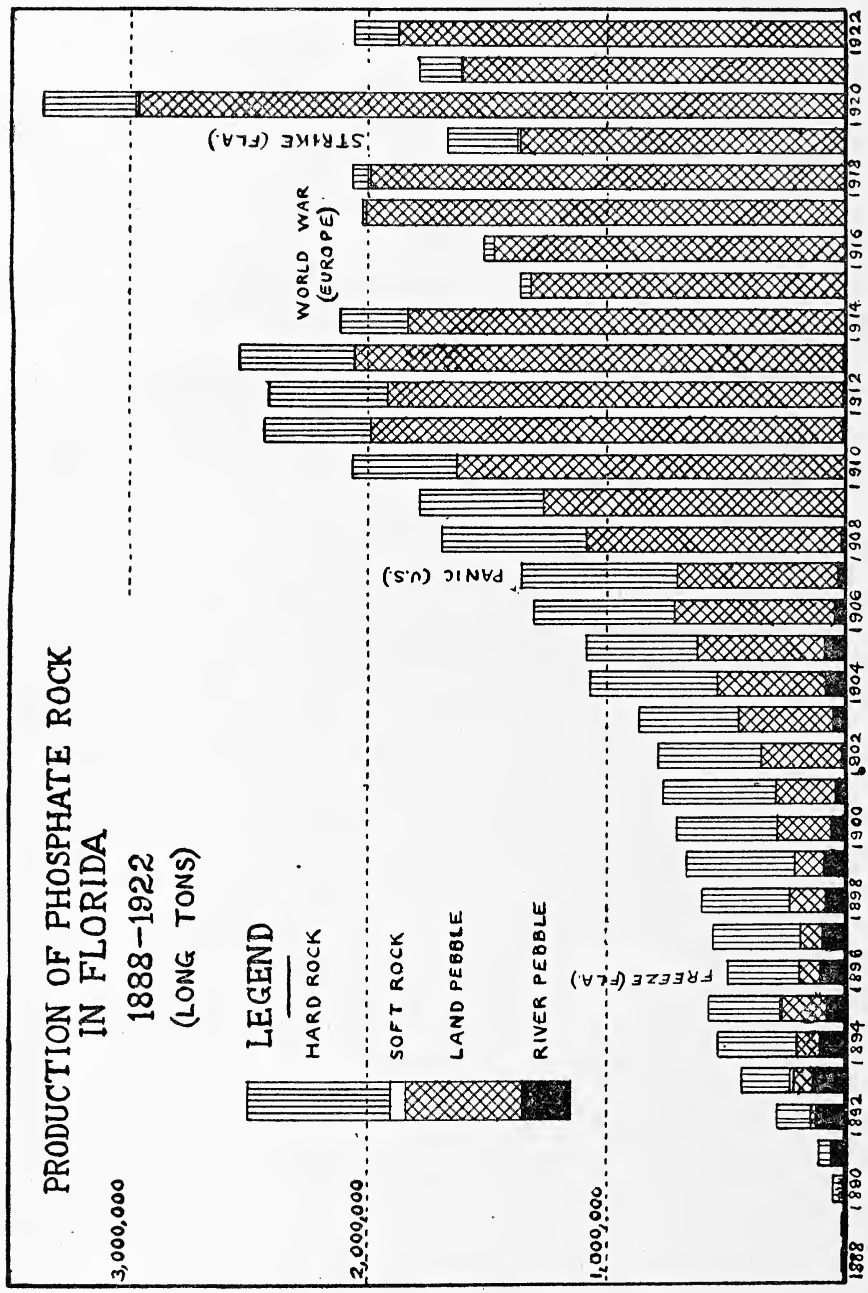
The following table gives the production and value of the four varieties of phosphate rock produced in Florida for the years 1900 to 1922, inclusive. Since the beginning of phosphate mining in 1888 to the close of 1922 Florida has produced 44,078,519 long tons with a total valuation of $175,097,242. These figures are in accordance with statistics collected by the United States Geological Survey and the Florida Geological Survey.

The chart on page 20, prepared by Dr. R. M. Harper, graphically illustrates the production of phosphate in Florida from the beginning of mining in 1888 to 1922. There is also indicated the causes of marked decline in the production for certain years such as for instance, the freeze of 1895, the panic of 1907, the World War, 1914 to 1918, the strike in the Florida pebble phosphate fields, 1919, and the depressed European conditions following the World War, 1921 and 1922.

PRODUCTION AND VALUE OF PHOSPHATE ROCK IN FLORIDA, 1900-1922.
(Long Tons)

Year	Land Pebble		Hard Rock		River Pebble		Soft Rock		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1900..	221,403	$ 612,703	424,977	$2,229,373	59,863	$ 141,236	....	$.........	706,243	$2,983,312
1901..	247,454	660,702	457,568	2,393,080	46,974	105,691	....	....	751,996	3,159,473
1902..	350,991	810,792	429,384	1,743,694	5,055	9,711	....	....	785,430	2,564,197
1903..	390,882	885,425	412,876	1,988,243	56,578	113,156	....	....	860,336	2,986,824
1904..	460,834	1,102,993	531,081	2,672,184	81,030	199,127	....	....	1,072,951	3,974,304
1905..	528,587	1,045,113	577,672	2,993,732	87,847	213,000	....	....	1,194,106	4,251,845
1906..	675,444	2,029,202	587,598	3,440,276	41,463	116,000	....	....	1,304,505	5,585,578
1907..	675,024	2,376,261	646,156	4,065,375	36,185	136,121	....	....	1,357,365	6,577,757
1908..	1,085,199	3,885,041	595,743	4,566,018	11,160	33,480	....	....	1,692,102	8,484,539
1909..	1,266,117	4,514,968	513,585	4,026,333	....	....	....	....	1,779,702	8,541,301
1910..	1,629,160	5,595,947	438,347	3,051,827	....	....	....	....	2,067,507	8,647,774
1911..	1,992,737	6,712,189	443,511	2,761,449	(a)	(a)	....	....	2,436,248	9,473,638
1912..	1,913,418	6,168,129	493,481	3,293,168	(a)	(a)	....	....	2,406,899	9,461,297
1913..	2,055,482	6,575,810	489,794	2,987,274	(a)	(a)	....	....	2,545,276	9,563,084
1914..	1,829,202	5,442,547	309,689	1,912,197	(a)	(a)	....	....	2,138,891	7,354,744
1915..	1,308,481	3,496,501	50,130	265,738	....	....	....	....	1,358,611	3,762,239
1916..	1,468,758	3,874,410	47,087	295,755	....	....	(b)	(b)	1,515,845	4,170,165
1917..	2,003,991	5,305,127	18,608	159,366	....	....	(b)	(b)	2,022,599	5,464,493
1918..	1,996,847	5,565,928	62,052	377,075	....	....	8,331	147,103	2,067,230	6,090,106
1919..	1,360,235	5,149,048	285,467	2,452,563	....	....	14,498	196,318	1,660,200	7,797,929
1920..	2,955,182	14,748,620	400,249	4,525,191	....	....	13,953	190,551	3,369,384	19,464,362
1921..	1,599,835	8,604,818	175,774	1,806,671	....	....	4,419	20,153	1,780,028	10,431,642
1922..	1,870,063	7,035,821	188,084	1,308,201	....	....	446	3,500	2,058,593	8,347,522

(a) Included in land pebble.
(b) Included in hard rock.


PRODUCTION OF PHOSPHATE ROCK
IN FLORIDA
1888–1922
(LONG TONS)
LEGEND
HARD ROCK
SOFT ROCK
LAND PEBBLE
RIVER PEBBLE
3,000,000
2,000,000
1,000,000
1888
1890
1892
1894
1896
1898
1900
1902
1904
1906
1908
1910
1912
1914
1916
1918
1920
1922
FREEZE (FLA.)
PANIC (U.S.)
WORLD WAR
(EUROPE)
STRIKE (FLA.)

LIST OF PHOSPHATE MINING COMPANIES OF FLORIDA, 1922

Acme Phosphate Co.	Morriston, Fla.
American Hard Rock Phosphate Co.	Floral City, Fla.
American Agricultural Chemical Co.	2 Rector St., New York, N. Y., and Pierce, Fla.
American Cyanamid Co.	511 Fifth Ave., New York, N. Y., and Brewster, Fla.
Armour Fertilizer Works	209 W. Jackson Blvd., Chicago, Ill., and Bartow, Fla.
Peter B. & Robert S. Bradley	92 State St., Boston, Mass., and Floral City, Fla.
J. Buttgenbach & Company	22 Ave. Marnix, Brussels, Belgium, and Dunnellon, Fla.
C. & J. Camp	Ocala, Fla.
Charleston, S. C., Mining & Manufacturing Co.	Richmond, Va., and Fort Meade, Fla.
Coronet Phosphate Co.	99 John St., New York, N. Y., and Plant City, Fla.
Cummer Lumber Co.	453 St. James Bldg., Jacksonville, Fla., and Newberry, Fla.
Downing Phosphate Co., Lessee, (Norfleet & Williams, Prop's)	Newberry, Fla.
Dunnellon Phosphate Co.	106 E. Bay St., Savannah, Ga., and Dunnellon, Fla.
Florida Phosphate Mining Corp.	P. O. Box 1118, Norfolk, Va., and Bartow, Fla.
Franklin Phosphate Co., (P. J. & J. H. Norfleet, Lessees)	Newberry, Fla.
Holder Phosphate Co.	3352 Jefferson Ave., Cincinnati, Ohio, and Inverness, Fla.
Independent Chemical Co., Inc.	33 Pine St., New York, N. Y., and Bowling Green, Fla.
International Agricultural Corp.	61 Broadway, New York, N. Y., and Mulberry, Fla.
Loncala Phosphate Co.	Ocala and Floral City, Fla.
Mutual Mining Co.	102 E. Bay St., Savannah, Ga., and Floral City, Fla.
Morris Fertilizer Co.	801 Citizens & Southern Bank Bldg., Atlanta, Ga., and Bartow, Fla.
Otis Phosphate Co., (P. J. & J. H. Norfleet, Lessees)	Benotis, Fla.
Palmetto Phosphate Co.	2 Rector St., New York, N. Y., and Pierce, Fla.
Phosphate Mining Co.	110 William St., New York, N. Y., and Nichols, Fla.
Peninsular Phosphate Corp.	215 Fourth Ave., New York, N. Y., and Ft. Meade, Fla.
Seminole Phosphate Co.	Croom, Fla.
Southern Phosphate Development Co.	Inverness, Fla.
Southern Phosphate Corp.	96 Wall St., New York, N. Y., and Mulberry, Fla.
Swift & Co.	Union Stock Yards, Chicago, Ill., and Bartow, Fla.

SAND AND GRAVEL

The sand produced in Florida is used principally in building for mixing in concrete and mortar. Other reported uses are, paving or road making and engine sand. The gravel is reported as being used only for paving and road making. The total production of sand and gravel in 1922 was 246,849 short tons, valued at $147,924.

Acme Sand Company, Leesburg.
Escambia Sand and Gravel Company, Flomaton, Ala., and Tarzan, Fla.
Crystal River Rock Company, Crystal River and Leesburg.
Florida Gravel Company, Quincy and River Junction.
Interlachen Sand and Gravel Company, Interlachen.
Lake Weir Washed Sand Company, Ocala.
Leesburg Sand and Supply Company, Leesburg.
Tallahassee Pressed Brick Company, Havana.
Tampa Sand and Shell Company, Tampa.
White Sand Company, Orlando.
A. T. Thomas Company, Ocala.

SAND-LIME BRICK

Two companies were actively engaged in the manufacture of sand-lime brick in Florida during 1922. The production and value is included in the table showing the total mineral production of the State for the years 1921 and 1922. The companies reporting production were:

Bond Sandstone Brick Company, Lake Helen.
Plant City Brick Company, Plant City and Tampa.

WATER

There was a decided increase in the output and in the total value of mineral waters sold in 1922 over that of 1921. Sales were reported from nine springs in the State and the total sales were 1,004,984 gallons with a valuation of $57,305. Among the producers of mineral waters in Florida are the following:

Name of Spring	*Location*
Crystal Springs	Crystal Springs, Pasco County.
Espiritu Santo Springs	Safety Harbor, Pinellas County.
Elixir Springs	Green Cove Springs, Clay County.
Flamingo Water Co.	Orange City, Volusia County.
Good Hope Mineral	Jacksonville, Duval County.
Gra-Rock Well	Miami, Dade County.
Heilbronn Springs	Starke, Bradford County.
Purity Springs	Tampa, Hillsboro County.
Panacea Mineral Springs	Panacea, Wakulla County.
Wekiva Springs	Apopka, Orange County.
Hampton Springs	Hampton Springs, Taylor County.
Newport Springs	Newport, Wakulla County.
White Sulphur Springs	White Springs, Hamilton County.
Wi-Wauchula Springs	Jacksonville, Duval County.

SUMMARY OF MINERAL PRODUCTION IN FLORIDA FOR 1921 AND 1922

Mineral Product	1921		1922	
	Quantity	Value	Quantity	Value
Phosphate (Long tons)				
Land pebble	1,599,835	$ 8,604,818	1,870,063	$ 7,035,821
Hard rock	175,774	1,806,671	188,084	1,308,201
Soft rock	4,419	20,153	446	3,500
Total Phosphates	1,780,028	10,431,642	2,058,593	8,347,522
Ball Clay, Fuller's Earth, Peat, Zircon, Ilmenite (Short tons)	86,294	1,504,574	107,684	1,666,260
Lime, Limestone and Flint (Short tons)	589,359	638,272	824,150	857,913
Common Brick, Pottery, Tile and Sand-Lime Brick	....	286,522	....	368,149
Sand and Gravel (Short tons)	160,445	97,324	246,849	147,924
Mineral Waters (Gallons)	321,472	28,365	1,004,984	57,305
Total Value		$12,986,699		$11,445,073

A CONTRIBUTION TO THE LATE TERTIARY AND QUATERNARY PALEONTOLOGY OF NORTHEASTERN FLORIDA.*

By

Wendell C. Mansfield

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CONTENTS.

INTRODUCTION.

After examining the molluscan fauna from the Pliocene calcareous marls in the vicinity of DeLand, Florida,[1] a more extensive comparison of this fauna and other faunas in northeastern Florida with that at the type locality of the Nashua marl seemed desirable.

At some of the localities considered in this paper the number of representative forms is small and at other localities many of the fossils are broken. It is hoped that future work in this field may supplement these collections.

Although some of the results obtained are not altogether conclusive, it is believed that an advance is made in the study of the relationship of the molluscan faunas of this part of the State.

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[1]Fla. State Geol. Survey, 11th Ann. Rept., pp. 111-123, 1918.

SOURCES OF THE FOSSIL MATERIAL

The collections considered in this paper are in the U. S. National Museum, and were made by Dr. T. Wayland Vaughan of the U. S. Geol. Survey, Dr. E. H. Sellards, then State Geologist of Florida, and Messrs. Geo. C. Matson, Frederick G. Clapp, and Otto Veatch.

Most of the material was collected in Putnam and Volusia counties; but one collection came from St. Mary's River at the north, three from the vicinity of Kissimmee, Osceola County, and four from localities along the Atlantic coast, between Daytona and Eau Gallie.

A few species from DeLeon Springs were determined by Dr. Wm. H. Dall, and are mentioned in his comprehensive work on the Tertiary fauna of Florida[1]. Specific identifications of many of the fossils were made by Dr. T. Wayland Vaughan, and listed in the Second Annual Report of the Florida Geological Survey, 1909. In working over the material, some of the specific identifications were changed, others queried, and some unidentified forms determined.

The following are the fossil localities considered in this paper; each collection has been given a U. S. Geological Survey station number which precedes the description of the locality:

4837—Two miles southeast of Eau Gallie, on peninsula south of point of Merritt's Island, Fla. Geo. C. Matson, collector.

4865—River bank, ¼-mile south of Nashua, Putnam Co., Fla., fossils from 15 ft. of white shell marl. F. G. Clapp, collector. (Type locality of the Nashua marl.)

4866—One-half mile above A. C. L. R. R. bridge over the St. Johns River, Putnam Co.; vertical cliff three to eight feet above high-water level. F. G. Clapp, collector.

5003—In a ditch 4 miles west of Eau Gallie, Brevard Co., Fla. Geo. C. Matson, collector.

5008—East side of St. Johns River, five miles below the Sanford railroad bridge, Volusia Co., Fla. Geo. C. Matson, collector.

5009—East side of St. Johns River, 7 miles below the Sanford railroad bridge, Volusia Co., Fla. Geo. C. Matson, collector.

5010—About half a mile south of DeLeon Springs station, Volusia Co., Fla. Eleven to seventeen feet below the surface. F. G. Clapp, collector.

5011—Half a mile north of R. R. station, Orange City, Volusia Co., Fla. F. G. Clapp, collector.

5012—Seven miles west of Titusville, Brevard Co., Fla. Geo. C. Matson, collector.

5016—Deep well at Kissimmee, Osceola Co., Fla. Fossils obtained at a depth of 65 to 100 feet. C. O. Newlands (driller).

5017—Near Michael's marlpit, one mile south of point, Daytona, Volusia Co., Fla. Geo. C. Matson, collector.

5019—A quarter of a mile south of railroad station, Orange City, Fla. Thirteen feet below surface. F. G. Clapp, collector.

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[1]Wagner Free Inst. Sci., Vol. III, 1890-1903.

Abra æqualis Say				?		+						?		+		+	+	+	?		+	+	+	+	+
Tagelus divisus Spengler				+								+						+				+	+	+	+
" gibbus "																		+			+	+	+	+	+
Donax fossor Say																			+		+	+	+	+	+
" variabilis Say	+			+	+					+		+		+			?		?					+	+
Labiosa canaliculata Say											?								+					+	+
Ervilia concentrica Gould																			+					+	+
Mulinia congesta (Conrad)								+			+										+	+			
Mulinia " near M. triquetra Conrad		+																			?	?	?	?	
" contracta (Conrad)							+									+	+				?	?	?	?	
" near M. caloosænsis Dall		+																			?	?	?	?	
" lateralis var. corbuloides Reeve				+	+	+						+			?				+		+	+	+	+	+
" " (heavy forms) var. A							+									+	+				?	?	?	?	
" " (long forms) " B	+	?	+	+			+		+			+	+	+		+	+	+	+		?	?	?	?	
" " (rounded forms) " C				+						+		+	+								?	?	?	?	
Rangia cuneata Gray												+										+	+	+	+
Corbula barrattiana C. B. Adams		+	+	+	+	+												+			?	+	+	+	+
" caloosæ Dall				+																			+		
" contracta Say			+															+				+	+	+	+
" inæqualis Say var. A							+						+			+	+				+	?			
" " " B		+					+						+			+	+				+	+			
Barnea costata Lamarck					+																		+	+	+

	4867. Eau Gallie, 2 mi. SE. of	4865. Nashua, ¼ mi. S. of	4866. Above A. C. L. bridge	5003. Eau Gallie, 4 mi. W. of	5008. 6 mi. below Sanford R.R. bridge	5009. 7 mi. below Sanford R.R. bridge	5010. DeLeon Springs, ½ mi. S. of	Earlier collections from DeLeon Springs	5011. Orange City Sta., ½ mi. N. of	5012. Titusville, 7 mi. W. of	5016. Well, Kissimmee	5017. Daytona	5019. Orange City R. R. Sta., ¼ mi. S. of	5143. Well, Kissimmee	5144. Id. L. Tohopekaliga	5834. DeLand, lower bed	5869. DeLand, upper bed	5898-7. Above A. C. L. bridge	7056. Rose Bluff	Geologic Range: Miocene	Pliocene (Waccamaw)	Pliocene (Caloosahatchee)	Pleistocene	Recent	Remarks
GASTROPODA																									
Actaeon punctostriatus Lea																	+			+		+	+	+	
Acteocina canaliculata (Say)			+		+							+			+			+		+	+	+	+	+	
Terebra concava Say		+							+								+			+	+	+	+	+	
" dislocata (Say)		+									+						+		+	+	+	+	+	+	
" kissimmeensis Mansfield n. sp.											+														
Conus marylandicus Green		+																		+	+				
Drillia thea Dall				+																				+	
" aff. D. limatula (Conrad)											+														Closer to Duplin forms
" tuberculata Emmons																	+			+	+	?			
Mangilia cerina Kurtz & Stimpson							+										+				+	+	+	+	
Oliva literata Lamarck		+		+			+		+		+		+			+	+			+	+	+	+	+	
Olivella mutica (Say)		+		+	+		+				+	+			+				+	+	+	+	+	+	
" nitidula Dillwyn													+			+	+			+	+	+	+	+	
Marginella aperina Menke				+							+										+	+	+	+	
" bella (Conrad)																	+			+	+	+	+	+	
" near M. bella (Conrad)							+										+								
" contracta Conrad							+													+	+				
" limatula Conrad		+															+			+	+	+	+	+	
Fasciolaria apicina Dall								+									+				+	+			
" distans Lamarck				+																			+	+	
" gigantea Kiener				+																+	+	+	+	+	
Busycon maximum Conrad var. ?	?	?		+																+	?	+			
" " var. (yo)													+												
" perversum (Linnaeus)		?		+	+												+			+	+	+	+	+	
" pyrum (Dillwyn)	+			+	+															+		+	+	+	
Melongena corona Gmelin	+						?															+	+	+	
Ilyanassa granifera var. sexdentifera Conrad		+																		+	+				
Ilyanassa isogramma Dall		?						+												+	+				
" porcina (Say) var. ?		+																		+	+				
Alectrion acuta (Say)				+	+							+						+	+		+		+	+	
" scalaspira (Conrad) ?											+									+					Range refers to species
" vibex (Say)				+	+																+	+	+	+	
Anachis avara var. translirata Ravenel		+																			+		+	+	
" obesa C. B. Adams			+															+			+		+	+	
" " " " var. ?																+	+				+		+	+	
Astyris lunata Say			+	+														+			+	+	+	+	
Columbella (Alia) watsoni Mansfield n. sp.											+														
Murex pomum Gmelin								+												?		+	+	+	
Eupleura caudata (Say), (poor spec.)				+																	+	+	+	+	
" near var. intermedia Dall		+																				+			Range refers to var.
Urosalpinx near U. perrugatus Conrad		+	+																		+	+	+	+	Range refers to species
Epitonium delandensis Mansfield																	+								
" aff. E. krebsii Mörch																+									
" lineatum (Say)															+		+								
" near E. sayana Dall			+																						
Turbonilla (Pyrgiscus) Sp. B		+															+					+	+		
" " Sp. A				+														+			?				
" (Chemnitzia) Sp. A																+									
Odostomia (Chrysallida) Sp. A												+					+	+			?				
Simnia uniplicata Sowerby																	+							+	
Triforis modesta C. B. Adams																		+		?		+	+	+	
Bittium varium Pfeiffer				+								+										+	+	+	
Cerithiopsis greenii C. B. Adams		+		+														?		+		+	+	+	
Cerithium muscarum Say				+								?		+								+	+	+	
Scala adamsii (H. C. Lea)																	+	+		+	+	+	+	+	
Caecum regulare Carpenter																		+				+	+	+	
" near C. carolinianum Dall																		+							
" putnamensis Mansfield n. sp.																		+							
" cooperi S. Smith																		+		+	+	+	+	+	
Turritella burdeni Tuomey & Holmes var. ?	?										+									+	?				
" aff. T. variabilis Conrad											+									+					Range refers to species
Littorina irrorata (Say)		+						+					+							+	+		+	+	
Rissoa gemea Dall																		+		+		+			
Rissoina chesneli Michaud			+															+				+	+	+	
Crepidula aculeata Gmelin var. costata Morton							+	+									+			+	+	+	+	+	
" convexa Say		?		+			+										+				+	+	+	+	
" fornicata (Linne)	+	+		+	?		+				+	+		+			+	+		+	+	+	+	+	
" plana Say							+				+	+						+		+	+	+	+	+	
Natica pusilla Say ?		+					+										+		+	+	+	+	+	+	Range refers to species
Polynices duplicatus (Say)								+			+						+		+	+	+	+	+	+	
Sinum perspectivum Say																	+		+				+	+	
Turbo crenulatus Gmelin								+													+	+	+	+	
Trinostoma near T. reclusa Say																		+							
Fissuridea alternata Say														+							+		+	+	
" carolinensis Conrad																	+			+	?	+			
SCAPHOPODA																									
Dentalium near D. attenuatum Say											+						+			+	?	?			Range refers to species
" n. sp. ? aff. D. carolinense Conrad		+																		+					Range refers to species
PELECYPODA																									
Nucula proxima Say				+	+							+			+			+	+	+	+	+	+	+	
Nucula proxima var. trinuculus Dall																+	+			+	+	+	+		
Leda acuta (Conrad)						+					+		+			+	+			+	+	+	+	+	
Leda trochilia Dall															+					+		?			
Glycymeris pectinata Gmelin														+						+	+	+	+	+	
Arca limula var. platyura Dall		+		+			+											?				+			
" " Conrad var. ?								+									+			+	+	+			
" ponderosa Say	+											+		+									+	+	
" (Scapharca) campechensis Dillwyn												+											+	+	
" " near A. campyla Dall		+	+		+	+																+			Range refers to the species
" " incongrua Say																			+				+	+	
" " plicatura Conrad							+										?			+	+				
" " scalarina Heilprin		+																			+	+			
" " subsinuata Conrad												+									?	?			Like form in Croatan
" " transversa Say (Light forms)							+	?				+	+	+		+	+	+	?		+		+		(Pliocene) of N. C.
" " " " (Heavy forms)	+			+								+									+	+	+	+	
Ostrea equestris Say														+										+	
" sculpturata Conrad		?	?														+			+	+	+			
" virginica Gmelin		+							+			+					+		+	?	+	+	+	+	
Pecten eboreus var. solaroides Heilprin		+															+					+			
" gibbus var. dislocatus Say														+						+	?	+	+	+	
Plicatula gibbosa Lamarck												+										+	+	+	
" marginata Say								+												+	+	+			
Anomia simplex d'Orbigny		+	+									+		+	+		+	+	+	+	+	+	+	+	
Crassatellites gibbesii Tuomey & Holmes																	+			+	+	+	+	+	
Crassinella near C. acuta Dall				+																	+	+			Range refers to species
" dupliniana Dall		+																		+	+				
" lunulata Conrad		+	+			+							+	+		+	+	+		+	+	+	+	+	
Venericardia perplana Conrad									+			+				+	+			+	+	+	+	+	
" tridentata Say				+	+		+		+	+		+	+			+	+			+	+	+	+	+	
Cardita arata (Conrad)			?				+	+					+							+	+	+			
" floridana Conrad				+										+				+				+	+	+	
Cardita osceolaensis n. sp. Mansfield											+														
Chama arcinella Linnaeus								+						+						+	+	+	+	+	
" congregata Conrad								+												+	+		+	+	
Codakia speciosa Rogers										+										+		+	+		
Phacoides near P. amiantus Dall				+																					
" crenulatus (Conrad)											+									+					
" multilineatus Tuomey & Holmes		+	+	+	?	+	+			+			+	?		+	+	+	+	+	+	+	+	+	
" nassulus Conrad var. ?				+										+									+		
" radians Conrad							+										+			+	+	+	+	+	Occurs at Grady
" trisulcatus near var. multistriatus Conrad		+									+									+					Range refers to species
" waccamawensis Dall		+																			+	+			
" " var. delandensis Mansfield							+						+			+	+								
Divaricella chipolana Dall var. ?		+																				+			
" quadrisulcata (d'Orbigny)																	+		+	+	+		+	+	
Diplodonta acclinis Conrad											+						+			+	+	+			
Sportella protexta Conrad																		+		+	+	+	+	+	
Rochefortia planulata Stimpson							+															+	+	+	
Cardium isocardia Linnaeus				+			+							?						+		+	+	+	
" cedalium Dall var.			+		+												+				+	+	?		
" robustum Solander	+		+	+			+												+	+	+	+	+	+	
Dosinia elegans Conrad		?	+															+		+	+	+	+	+	
Transennella caloosana Dall				+		+								+						+		+	+		
" stimpsoni Dall				+																				+	
Gafrarium metastriatum (Conrad)		+											+				+			+	+	+			
Macrocallista nimbosa Solander			+																		+	+	+	+	
Callocardia sayana (Conrad)														+						+	+	+			
Chione cancellata Linnaeus	+	+	+	+	+	+	+	+				+		+	?			+				+	+	+	
" grus (Holmes)				+								+		+						+	+	+	+	+	
" latilirata (Conrad)																	+			+	+	+	+	+	
Anomalocardia brasiliana Gmelin														+								+	+	+	
" caloosana Dall				+	?	+						+										+	+		
Venus campechiensis Gmelin	+			+	+							+								+	+	+	+	+	
" rileyi Conrad							+		+								+			+	+	+	?		
" tridacnoides Lamarck ?		+																							
Gemma magna Dall		+													+					+	+	+	+		
" trigona delandensis Mansfield									+				+			+	+								
" purpurea H. C. Lea					+							+											+	+	
" trigona Dall															+					+	+	+			
Parastarte triquetra Conrad					+							+								+		+	+	+	
Petricola pholadiformis Lamarck				+																			+	+	
Tellina declivis Conrad																	+		+	+		+	+		
" polita Say				+		+												+			?	+	+	+	
" cf. T. propetenera Dall						+																+			Range refers to species
" tampaensis Conrad												+										+	+	+	
Strigilla flexuosa Say																			+	+	+	+	+	+	
Semele bellastriata Conrad				+								?									+	+	+	+	
" proficua Pulteney			?			?												+			+	+	+	+	
Abra aequalis Say						+								+		+	+	+	?	+	+	+	+	+	
Tagelus divisus Spengler				+								+						+			+	+	+	+	
" gibbus "																		+		+	+	+	+	+	
Donax fossor Say																			+	+	+	+	+	+	
" variabilis Say	+			+	+					+		+		+			?		?				+	+	
Labiosa canaliculata Say											?								+				+	+	
Ervilia concentrica Gould																			+				+	+	
Mulinia congesta (Conrad)								+			+									+	+				
Mulinia " near M. triquetra Conrad		+																		?	?	?	?		
" contracta (Conrad)							+									+	+			?	?	?	?		
" near M. caloosaensis Dall		+																		?	?	?	?		
" lateralis var. corbuloides Reeve				+	+	+						+			?				+	+	+	+	+	+	
" " (heavy forms) var. A							+									+	+			?	?	?	?		
" " (long forms) " B.	+	?	+	+			+		+			+	+	+		+	+	+	+	?	?	?	?		
" " (rounded forms) " C				+						+		+	+							?	?	?	?		
Rangia cuneata Gray												+									+	+	+	+	
Corbula barrattiana C. B. Adams		+	+	+	+	+												+		?	+	+	+	+	
" caloosae Dall				+																		+			
" contracta Say			+															+			+	+	+	+	
" inaequalis Say var. A							+						+			+	+			+	?				
" " " " B		+					+						+			+	+			+	+				
Barnea costata Lamarck					+																	+	+	+	

5143—Well at Kissimmee, Osceola Co., Fla., depth 96 feet from surface. T. W. Vaughan, collector.
5144—From well of Mary Boss, on island in Lake Tohopekaliga, about three miles from Kissimmee, Fla., depth 150 feet. T. W. Vaughan, collector.
5634—From lower marl stratum at city marlpit about one mile south of DeLand, Volusia Co., Fla. E. H. Sellards, collector.
5869—From upper marl stratum at city marlpit, about one mile south of DeLand, Volusia Co., Fla. E. H. Sellards, collector.
6096-6097—Half a mile above A. C. L. R. R. bridge over St. Johns River, Putnam Co., Fla., 5 to 7 ft. below the surface and the same distance above high-water level. F. G. Clapp, collector.
7056—Rose Bluff, Nassau Co., Fla., opposite to and four miles southwest of St. Mary's, Camden Co., Ga. Otto Veatch, collector.

NASHUA MARL

NAME AND ORIGINAL DESCRIPTION

The name Nashua marl was proposed by G. C. Matson and F. G. Clapp[1] who give the following description:

"During the progress of the field work for this report, collections of fossils were obtained which indicate that Pliocene marls are extensively developed in the valley of the St. Johns River, and a bed of similar marl near Daytona has been referred to the same period. These beds have certain faunal elements which distinguish them from the other Pliocene beds of Florida; and, hence, they are given a distinct name. They are here designated the Nashua marl, from a locality on the St. Johns River, where they are best exposed. Further study may result in uniting all of the marine Pliocene of Florida under a single name; but for the present it appears desirable to avoid hasty correlation by the use of local names for the beds of different localities, especially where conditions governing deposition appear to have been unlike.

"*Stratigraphic Position:*—The Nashua marl is thought to rest unconformably upon the Miocene at DeLand; but this opinion lacks confirmation, as the collections from that locality have not been studied in sufficient detail to determine the exact age of the beds. At various localities, the contact between this formation and the overlying Pleistocene sand has been observed and it is everywhere marked by a distinct unconformity. The Pleistocene beds rest upon an undulating surface of the Nashua marl, which is clearly due to erosion, and the contrast

[1]Matson, G. C., and Clapp, F. G. A preliminary report of the geology of Florida with special reference to the stratigraphy. Fla. State Geol. Survey, 2nd Ann. Report, pp. 128-130, 1909.

between the fossiliferous marl and the overlying barren sands helps to emphasize the break between the two.

"*Lithologic Character:*—The Nashua marl bears a strong lithologic resemblance to the Caloosahatchee marl. There is the same alternation of sand beds with shell marl. The matrix of the Nashua marl, while usually calcareous, is always more or less sandy and sometimes consists of nearly pure sand. The shells are commonly well preserved though locally a marl consisting of broken and eroded fragments of shells is not uncommon. However, the organic remains are so well preserved that it is easy to obtain good collections of fossils from this formation.

"*Thickness:*—The Nashua marl is much thinner than the Miocene strata. This fact, together with its distribution beneath the lowlands near the coast, indicates that the Pliocene submergence was less extensive than the Miocene; and the presence of shallow-water fossils shows that the Pliocene sea did not attain any great depth over that part of the State where the marine beds are now exposed. The Nashua marl is seldom more than six or eight feet thick, but locally it attains a greater thickness. A series of samples of sand and marl from a well at DeLand indicates that at that locality this marl has a thickness of about thirty-two feet.

"*Physiographic Expression:*—The Nashua marl occupies the St. Johns Valley, where it underlies a broad terrace bordering the stream. It probably occurs beneath the plain east of St. Johns River, but the overlying Pleistocene forms such a thick mantle that the Nashua marl has no influence on the topography. On the whole, this formation has little or no influence on the topography of the State.

"*Paleontologic Character:*—The fauna of the Nashua marl is only imperfectly known, but it has been sufficiently studied to show that it resembles that of the Caloosahatchee marl. The most striking difference between the faunas of the two formations is the existence of certain species in the Nashua marl which occur in the 'Waccamaw' fauna of the Carolinas, but are not known to be present in the Caloosahatchee marl. This affinity with the fauna to the north suggests the existence of a cold current along the Atlantic coast which permitted a southward migration of the 'Waccamaw' fauna. The lack of exposures in the south-central portion of the peninsula prevents the tracing the connection

between the two formations and the determination of the limits of the southward migration of the species from the 'Waccamaw' fauna.

"*Structure:*—The Nashua marl is exposed at only a few localities in the St. Johns Valley and it is difficult to form any definite idea concerning its structure. It has probably been subjected to the same deformation as the Caloosahatchee marl, but the isolated exposures afford no opportunity to observe evidences of folding. The dip is doubtless seaward and it is probably very slight.

"*Local Details:*—In the St. Johns Valley there are a number of exposures of the Pliocene marl which have been designated the Nashua marl. At the type locality, one-fourth mile south of Nashua, Putnam County, there is an exposure of five feet of white sand, resting unconformably upon about fifteen feet of white shell marl. . . ."

LISTS OF SPECIES FROM THE NASHUA MARL

4865.—A quarter of a mile south of Nashua, Putnam Co., Fla. (Type locality of the Nashua marl). (See Matson, G. C., and Clapp, F. G., Fla. Geol. Survey, 2nd Ann. Rep't p. 130, 1909.)

Approved or Changed.	**Original.**
Terebra protexta (Conrad), not found.	Terebra protexta Conrad.
Terebra dislocata (Say).	Terebra dislocata Say.
Terebra concava (Say), var. (?)	Terebra concava Say.
Conus marylandicus Green.	Conus marylandicus Green.
Oliva literata Lam'k.	Oliva literata Lamk.
Olivella mutica (Say).	Olivella mutica Say.
Marginella limatula Conrad.	Marginella pardalis Dall.
Marginella cf. M. floridana Dall.	Volutella amiantula Dall.
Busycon maximum Conrad (?) (yo.).	Fulgur maximum Conrad.
Eupleura miocenica, var. near intermedia Dall.	Eupleura miocenica var. intermedia Dall.
Urosalpinx, near perrugatus Conrad.	Murex pomum Linn.
Ilyanassa porcina (Say), var. (?)	Ilyanassa porcina Say.
Ilyanassa isogramma Dall (?)	Ilyanassa isogramma Dall.
Ilyanassa granifera, var. sexdentata Conrad.	Ilyanassa granifera Conrad.
Ilyanassa porcina (Say), var.	Nassa scalaspira Dall.
Anachis avara, var. translirata Ravenel.	Anachis avara var. caloosænsis Dall.
Turbonilla.	Turbonilla.
Eulima.	Eulima.
Cerithiopsis greeni C. B. Ads.	Cerithiopsis greeni C. B. Ads.
Crucibulum cf. C. auricula Gmelin (yo.).	Crucibulum auricula Gmelin.
Crepidula convexa Say, (?) (yo.).	Crepidula convexa Say.
Natica pusilla Say (?).	Natica (Cryptonatica) pusilla Say.
Littorina irrorata (Say).	Littorina irrorata Say.
Dentalium, near D. carolinense Conrad.	Dentalium carolinense Conrad.
Arca (Nœtia) limula, var. platyura Dall.	Arca (Nœtia) limula, var. platyura Dall.

Arca, near A. campyla Dall.	Arca campyla Dall.
Ostrea virginica Gmelin.	Ostrea virginica Gmelin.
Pecten eboreus, var. solaroides Heilprin.	Pecten madisonius Say.
Anomia simplex Orbigny.	Anomia simplex Orb.
Crassinella lunulata Conrad.	Crassinella lunulata Conrad.
Crassinella dupliniana Dall.	Crassinella acuta Dall.
Phacoides waccamawensis Dall.	Phacoides tuomeyi Dall.
Phacoides multilineatus T. and H.	Phacoides multilineatus T. and H.
Divaricella chipolana Dall, var. (?)	Davircella chipolana Dall, var. ?
Arca scalarina Heilprin.	Cardium robustum Sol.
Venus tridacnoides Lamarck. (?)	Venus tridacnoides Lam.
Dosinia elegans Conrad.	Dosinia, young—D. elegans Conrad?
Chione cancellata Linne, not found.	Chione cancellata Linn.
Gemma magna Dall.	Gemma magna Dall.
Gafrarium metastriatum (Conrad).	Pitaria (?) Young.
Mulinia, near M. caloosæensis Dall.	Mulinia congesta Conrad.
Mulinia, near M. triquetra Conrad.	Mulinia congesta var. triquetra Conrad.
Corbula barrattiana C. B. Ads.	Corbula cuneata Say.

Species not originally listed from this station:

Crepidula fornicata (Linne).
Ostrea sculpturata Conrad (?) (young).
Phacoides trisulcatus near var. multistriatus Conrad.
Corbula inæqualis Say, var. B.

Geologic horizon originally reported: Pliocene.

Geologic horizon believed to be in this report: Pliocene.

5010.—Half a mile south of DeLeon Springs station, Volusia Co., Fla. Eleven to seventeen feet below the surface (see Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't Fla. Geol. Survey, 1909, p. 132.)

Approved or Changed.	Original.
Marginella contracta Conrad.	Marginella contracta Conrad.
Terebra dislocata (Say) (?) (yo.).	Terebra dislocata Say.
Oliva literata Lamarck.	Oliva literata Lam.
Melongena corona Gmelin (?) (yo.).	Melongena corona Gmel.
Crepidula convexa Say.	Crepidula convexa Say.
Crepidula aculeata Gmel.	Crepidula aculeata Gmel.
Crepidula plana Say.	Crepidula plana Say.
Cryptonatica pusilla Say (?)	Cryptonatica pusilla Say.
Arca transversa Say.	Arca transversa Say.
Arca limula, var. platyura Dall.	Arca ponderosa Say.
Arca limula, var. platyura Dall.	Arca limula, var. platyura Dall.
Arca plicatura Conrad.	Arca plicatura Say.
Pecten gibbus Linne.	Pecten gibbus Linn.
Carditamera arata Conrad.	Carditamera arata Conrad.
Venericardia tridentata Say.	Venericardia tridentata Say.
Phacoides multilineatus Tuomey and Holmes.	Phacoides multilineatus T. and H.
Phacoides waccamawensis, delandensis Mansfield.	Phacoides waccamaensis Dall.
Phacoides radians Conrad.	Phacoides radians Conrad.
Cardium robustum Solander.	Cardium robustum Solander.

Cardium isocardia Linne.	Cardium isocardia Linn.
Venus rileyi Conrad.	Venus campechiensis Gmel.
Chione cancellata Linne.	Chione cancellata Linn.
Mulinia lateralis Say.	Mulinia lateralis Say.
Corbula inæqualis Say (2 vars.).	Corbula inæqualis Say.

Other species not originally reported from this station are:

Mangilia cerina Kurtz and Stimpson.
Olivella mutica (Say).
Marginella, near M. bella (Conrad).
Crepidula fornicata (Linne).
Rochefortia planulata Stimpson.
Gemma magna Dall. (?)
Mulinia contracta (Conrad).

Geologic horizon originally reported: Pliocene.
Geologic horizon in this report: Pliocene (Nashua marl).

The following species are cited from DeLeon Springs with assigned age by Dr. Wm. H. Dall, in the Transactions of the Wagner Free Institute of Science of Philadelphia, Vol. III:

Crepidula aculeata Gmel. { (p. 357); Pliocene.
{ (p. 1597); Miocene.
Ilyanassa isogramma Dall, (p. 239); Pliocene (?)
Littorina irrorata Say, (p. 320); Pliocene.
Carditamera arata Conrad, (p. 1414); Pliocene.
Carditamera arata Conrad, (p. 1597); Miocene.
Chama congregata Conrad, (p. 1400); Miocene.
Echinochama arcinella Linne, (p. 1597); Miocene.
Echinochama arcinella Linne, (p. 1612); Pliocene.

5019.—One-fourth of a mile south of the railroad station at Orange City, Fla., basal member. (See Matson, G. C., and Clapp, F. G., Fla. Geol. Survey, 2nd Ann. Rep't, p. 149, 1909.)

Approved or Changed.	Original.
Melampus lineatus Say, var.	Melampus lineatus Say.
Terebra concava (Say), not found.	Terebra concava Say.
Olivella nitidula Dillwyn.	Olivella mutica Say.
Oliva literata Lamarck.	Oliva literata Lam.
Busycon maximum var. (yo.).	Fulgur pyriformis Conrad.
Litorina irrortata (Say).	Littorina irrorata Say.
Leda acuta (Conrad), var.	Leda acuta Conrad.
Arca transversa Say.	Arca transversa Say.

Other species from this station not listed with the above are:

Crassinella lunulata Conrad.
Venericardia tridentata Say.
Cardita arata (Conrad).
Phacoides multilineatus Tuomey and Holmes.

Phacoides waccamawensis delandensis Mansfield.
Gafrarium metastriatum (Conrad).
Gemma trigonia delandensis Mansfield.
Mulinia lateralis Say, (2 vars.)
Corbula inæqualis Say, (2 vars.)

Geologic horizon given with the original list: Pleistocene (?)

Geologic horizon believed to be in this report: Pliocene (Nashua marl).

Following is a list of fossils collected by Mr. F. G. Clapp from one-half mile north of the railroad station, Orange City, Fla.

Sta. No. 5011:

Terebra concava (Say).
Oliva literata Lam. var. (?)
Arca transversa Say (?)
Ostrea virginica Gmelin.
Venericardia perplana Conrad.
Venericardia tridentata Say.
Venus rileyi Conrad.
Gemma trigona delandensis Mansfield.
Mulinia lateralis Say.

Geologic horizon: Pliocene (Nashua marl).

Sta. No. 5869 (No. 3 of section) and 5634 (No. 1 of section). Marl-pit about one mile south of DeLand, Volusia Co., Fla. (For original list of species see Mansfield, W. C., Fla. State Geol. Survey, 11th Ann. Rep't, pp. 113-115, 1918.)

Geologic horizon: Pliocene (Nashua marl).

AGE OF THE NASHUA MARL

The fossils from the type locality of the Nashua marl were identified by Dr. T. W. Vaughan, who makes the following statement[1] in referring to the geologic age: "Pliocene, [though] the presence of *Pecten madisonius* suggests the presence of Miocene in the same bluff. The fauna has an additional interest in containing species found in the 'Waccamaw beds' but not in the Caloosahatchee." The present writer believes this *Pecten* is *P. eboreus* var. *solaroides* Heilprin, a Pliocene variety found in the Caloosahatchee marl. Another form is listed, *Mulinia congesta* (Conrad), which is believed to be closely allied to *M. caloosaensis* Dall. Even granting that this variable species (*Mulinia*

[1]Fla. State Geol. Survey, 2nd. Ann. Rep't, p. 130, 1909.

congesta) occurs in the Nashua marl, its presence has been reported from the Croatan beds of North Carolina.

The close relationship of the fauna of the Nashua marl at its type locality to that of the Waccamaw is indicated on the correlation sheet. When 28 of the better preserved forms from the Nashua marl are compared with other faunas, about 75 per cent occur in the Caloosahatchee, and 57 per cent are represented in the Recent fauna. None are found to be exclusively Miocene and five appear to be confined to the Pliocene. The following three appear to be diagnostic Pliocene species,—*Arca limula* var. *platyura* Dall, *Arca scalarina* Heilprin, and *Phacoides waccamawensis* Dall. The conclusion deduced from the foregoing facts places the Nashua marl at its type locality in the Pliocene, apparently the basal Pliocene, and stratigraphically equivalent to the beds referred to the Waccamaw marl in the Carolinas.

It is believed by the writer, relying upon data at hand, that no faunas considered in this paper, excepting those in deep wells at or near Kissimmee, are older than the Pliocene, and if the Miocene is present in this area, it is found only in well borings. This belief is founded not only upon the facies of the fauna, but upon the absence of diagnostic Miocene species such as occur in known upper Miocene deposits of the southeastern United States. The following five will be cited followed by these indices of their occurrence:

A. Alum Bluff, Fla.—upper bed.
C. Coe's Mill, Fla.
D. Natural Well, or Duplin of N. C.
M. Duplin at Mayesville, S. C.
J. Jackson Bluff, Fla.
T. Tallahassee, Fla. (16 mi. S. W.)

Arca scalaris Conrad, A. C. D. M.
Phacoides tuomeyi Dall, C. D. M. J. T. (Reported in the Pliocene at Walker's Bluff and Neill's Eddy Landing, N. C.)
Dentalium attenuatum Say, A. D. J. M.
Ecphora quadricostata Say, A. D. M.
Turritella variabilis Conrad, A. J. M. T.

Of these species, none are found with certainty among the fauna referred to the Nashua marl.

MIOCENE AT KISSIMMEE

The following is a new list of fossils said to have been taken between depths of 65 and 100 feet in a well at Kissimmee, Osceola Co., Fla., C. O. Newlands, driller. Station 5016:

Terebra dislocata (Say).
Terebra (Acus) kissimmeënsis n. sp.
Drillia aff. D. limatula (Conrad).
Oliva literata Lamarck.
Olivella mutica (Say).
Marginella apicina Menke, var.
Alectrion scalaspira (Conrad) (?)
Columbella (Alia) Matsoni, n. sp.
Turritella burdeni T. and H., var. (?)
Turritella aff. T. variabilis Conrad, (?) (yo.).
Crepidula fornicata (Linne).
Crepidula plana Say.
Polynices duplicatus (Say).
Dentalium, near D. attenuatum Say.
Leda acuta (Conrad).
Arca transversa Say (?) (frag.).
Cardita osceolaënsis n. sp.
Phacoides crenulatus (Conrad).
Phacoides, near var. multistriatus Conrad.
Diplodonta acclinis Conrad.
Mulinia congesta (Conrad).

Geologic horizon: Miocene and probably also some post-Miocene.

The presence of the species *Drillia* aff. *D. limatula, Turritella burdeni* var. (?), *Dentalium,* near *D. attenuatum,* and *Mulinia congesta* (Conrad) (heavy forms) indicate Miocene age.

5144.—Fossils obtained at a depth of 150 feet in the well of Mary Boss, on an island in Lake Tohopekaliga, about 3 miles from Kissimmee, Florida. (See Matson, G. C., and Clapp, F. G., Fla. State Geol. Survey, 2nd Ann. Rep't, p. 133, 1909.)

Revised List.	Original List.
Acteocina canaliculata (Say).	Tornatina canaliculata Say.
Olivella mutica (Say).	Olivella mutica Say.
Marginella (fragment).	Marginella fragment.
Epitonium aff. E. lineatum (Say) (yo.).	Scala lineata Say.
Turritella subannulata Heilprin (?) (yo.).	Turritella subannulata Hpn.
Turritella burdeni T. and H. (?)	Turritella apicalis Hpn.
Crucibulum auricula Gmelin (?) (yo.).	Crucibulum auricula Gmel.
Dentalium, near D. attenuatum Say.	Dentalium caloosænse Dall.
Cadulus quadridentatus Dall (?)	Cadulus quadridentatus Dall (?)
Nucula proxima Say.	Nucula proxima Say.
Leda trochilia Dall.	Leda n. sp., also Pliocene of Shell Creek.
Pecten gibbus Linné (?) (frag.).	Pecten gibbus Linn.
Anomia simplex Orbigny.	Anomia simplex Orb.
Venericardia tridentata Say (?) (yo.).	Venericardia tridentata Say.
Phacoides multilineatus T. and H. (?)	Phacoides, worn specimens.
Callocardia sayana (Conrad) (?) (yo.).	Callocardia sayana Conrad.
Chione cancellata L. (?) (yo.).	Chione cancellata Linn.

Gemma trigona Dall.	Gemma trigona Dall.
Gemma magna Dall.	Gemma sp.
Parastarte triquetra Conrad, not found.	Parastarte triquetra Conrad.
Ensis (fragment).	Ensis, fragment.
Mulinia lateralis Say, var. carbuloides Reeve (?)	Mulinia lateralis Say.
Balanus sp.	Balanus sp.

Geologic horizon given in the original report: Pliocene.

Geologic horizon believed to be in this report: Probably Miocene, including some Pliocene.

The presence of the species *Dentalium,* near *D. attenuatum, Leda trochilia,* and *Turritella burdeni* (?) suggest Miocene. *Leda trochilia* is common in the Miocene. There are in the National Museum collection, three or four specimens from the Caloosahatchee Pliocene very near *Leda trochilia,* but *Leda acuta* is the most common species there.

LATE PLIOCENE OR EARLY PLEISTOCENE DEPOSITS

5009.—East side St. Johns River, seven miles below the railroad bridge near Sanford, Fla. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't Fla. Geol. Survey, 1909; p. 133.)

Approved or Changed.	Original.
Arca, near A. campyla Dall.	Arca campyla Dall.
Crassinella lunulata Conrad.	Crassinella lunulata Conrad.
Phacoides multilineatus T. and H.	Phacoides multilineatus T. and H.
Chione cancellata Linné.	Chione cancellata Linn.
Transenella caloosana Dall.	Transennella caloosana Dall.
Anomalocardia caloosana Dall.	Anomalocardia caloosana Dall.
Semele proficua Poulteney (?)	Semele.
Abra æqualis Say.	Abra æqualis Say.
Corbula barrattiana C. B. Adams.	Corbula contracta Say.

Other species from this station not originally reported with the above list are:

Leda acuta (Conrad).
Tellina polita Say.
Tellina cf. T. propetenera Dall.
Mulinia lateralis var. corbuloides Reeve.

Geologic horizon given in original report: Probably Pliocene.

Geologic horizon believed to be in this report: uppermost Pliocene or lowest Pleistocene.

Arca campyla appears to be confined to the Pliocene. The form in this collection is nearer to this species although not typical.

5008.—East side of the St. Johns River, five miles below the Sanford railroad bridge. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't of Fla. Geol. Survey, 1909; p. 132.)

Approved or Changed.	Original.
Acteocina canaliculata (Say).	Tornatina canaliculata Say.
Olivella mutica (Say).	Olivella mutica Say.
Busycon pyrum (Dillwyn).	Fulgur pyrum Dillwyn.
Busycon perversum (Linné).	Fulgur perversum Linné.
Not found.	Nassa elevata Say.
Alectrion vibex (Say).	Nassa vibex Say.
Crepidula fornicata Say (?) (yo.).	Crepidula fornicata Say.
Nucula proxima Say.	Nucula proxima Say.
Arca, near A. campyla Dall.	Arca transversa Say.
Mytilus venustus Linné.	Mytilus venustus Linn.
Phacoides multilineatus T. and H.	Phacoides multilineatus T. and H.
Cardium œdalium Dall (not typical, approaching C. muricatum Linné.	Cardium œdalium Dall.
Lævicardium mortoni Conrad (?)	Lævicardium serratum Linn.
Anomalocardia caloosana Dall (?) (young).	Anomalocardia caloosana Dall.
Venus campechiensis Gmel.	Venus campechiensis Gmel.
Chione cancellata Linné.	Chione cancellata Linn.
Tellina declivis Conrad.	Tellina declivis Conrad.
Corbula barrattiana C. B. Ad's.	Corbula contracta Say.
Mulinia lateralis, var. corbuloides Rve.	Mulinia lateralis Say.
Pholas costata Lamarck.	Pholas costata Lam.

Other species from this station not originally reported in above list are:

Alectrion acuta (Say). This may be the same form as listed as *Nassa elevata* Say.
Venericardia tridentata Say.
Parastarte triquetra Conrad.
Donax variabilis Say.
Gemma purpurea H. C. Lea.

Geologic horizon given with the original report: "Probably Pliocene."

Geologic horizon believed to be in this report: Upper Pliocene or lowest Pleistocene.

The two species, *Donax variabilis* and *Gemma purpurea,* as noted, were not listed in the original report. The two species appear to be exclusively post-Pliocene. If they came from the same stratum as the other listed species, the age would indicate post-Pliocene rather than Pliocene.

4866.—Half a mile above A. C. L. R. R. Bridge over St. Johns River, Putnam Co., Fla. Vertical cliff three to eight feet above high-water level. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't Fla. Geol. Survey, 1909; p. 131.)

Approved or Changed.	Original.
Acteocina canaliculata (Say).	Tornatina canaliculata Say.
Urosalpinx, near U. perrugatus (Conrad).	Urosalpinx perrugatus Conrad.
Astyris lunata Say.	Astyris lunata Say.
Anachis obesa (C. B. Ads.).	Anachis.
Anachis obesa (C. B. Ads.).	Anachis.
Epitonium, near E. sayana (Dall).	Scala.
Crepidula convexa Say (?) (yo.).	Crepidula convexa Say.
Rissoina chesnelii (Michaud).	Rissoina chesneli Mich.
Arca, near A. campyla Dall.	Arca campyla Dall.
Ostrea sculpturata Conrad (?) (yo.).	Ostrea.
Modiolus.	Modiolus.
Crassinella lunulata Conrad.	Crassinella lunulata Conrad.
Carditamera arata Conrad (?) (yo.).	Carditamera arata Conrad.
Phacoides multilineatus T. and H. not found.	Phacoides multilineatus T. and H.
Lucina.	Lucina.
Cardium œdalium Dall, var. (not typical), near C. muricatum Linn.	Cardium œdalium Dall.
Cardium robustum Solander.	Cardium robustum Sol.
Chione cancellata Linn.	Chione cancellata Linn.
Dosinia elegans Conrad.	Dosinia elegans Conrad.
Macrocallista nimbosa Solander.	Macrocallista nimbosa Sol.
Semele proficua Poulteney (?)	Semele purpurea Gmel. ?
Mulinia lateralis Say.	Mulinia lateralis Say ? yo.
Corbula barrattiana C. B. Adams.	Corbula cuneata Say.
Corbula contracta Say, (not originally reported).	
Anomia simplex d'Orb., (not originally reported).	

Geologic horizon originally reported: Pliocene.

Geologic horizon believed to be in this report: Uppermost Pliocene or early Pleistocene.

Arca, near *A. campyla* and *Cardium oedalium* var. and *Ostrea sculpturata* (?) strongly indicate Pliocene age rather than later.

6096-7.—Half a mile above the A. C. L. R. R. bridge over St. Johns River, Putnam Co., Fla., five to seven feet below surface and 5 to 7 ft. above high-water level. F. G. Clapp, collector.

This lot is apparently from the same locality as station 4866, but contains species not originally reported from there:

Acteocina canaliculata (Say).
Alectrion acuta (Say).
Anachis obesa (C. B. Ads.).
Astyris lunata Say.
Turbonilla (Pyrgiscus) sp. A.
Odostomia (Chrysallida) sp. A.
Triforis modesta C. B. Ads.
Cerithiopsis greenii C. B. Ads.
Seila adamsii (H. C. Lea).
Cæcum regulare Carpenter.

Cæcum, near C. carolinianum Dall.
Cæcum putnamensis n. sp.
Cæcum cooperi Smith.
Rissoa geræa Dall.
Rissoina chesnelii (Mich.).
Crepidula fornicata (Linné).
Crepidula plana Say.
Teinostoma, near T. reclusa Say.
Nucula proxima Say.
Arca limula, var. platyura Dall (?)
Arca transversa Say, (light form).
Anomia simplex Orbigny.
Crassinella lunulata Conrad.
Cardita floridana Conrad.
Phacoides multilineatus T. and H.
Sportella protexta Conrad.
Dosinia elegans Conrad.
Chione cancellata Linné.
Tellina polita Say.
Semele proficula Poulteney.
Abra æqualis Say.
Tagelus divisus Spengler.
Mulinia lateralis Say, var. B.
Corbula barrattianna C. B. Ads.
Corbula contracta Say.

Geologic horizon: Uppermost Pliocene or lowest Pleistocene.

PLEISTOCENE DEPOSITS

COMMENTS ON FAUNAS FROM FORMERLY REPORTED LOCALITIES

7056.—Rose Bluff, Nassau Co., Florida. Opposite to and 4 miles west of St. Mary's, Camden Co., Ga. (See Ga. Geol. Surv. Bull. No. 26, p. 436, 1911, for fossil list).

Geologic horizon given in original report: Pleistocene.

Geologic horizon believed to be in this report: Pleistocene.

The fauna at this locality is related to that at station 5869 (DeLand, stratum No. 3 of section) as approximately 50 per cent of the Rose Bluff species are represented in that stratum; but the fauna from Rose Bluff contains certain species, as *Arca incongrua, Ervilia concentrica,* and probably *Donax variabilis,* that appear to occur only in deposits of post-Pliocene age.

5143.—Well at Kissimmee, Osceola Co., Fla.; depth 96 ft. from surface. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't Geol. Surv., 1909, pp. 149-150 for list.)

Geologic Horizon given in original report: Pleistocene.

Geologic Horizon believed to be in this report: Pleistocene.

Two species from this locality, *Ostrea equestris* Say, and *Donax variabilis* Say, are believed to be exclusively post-Pliocene and Recent.

5003.—In a ditch 4 miles west of Eau Gallie. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't Fla. Geol. Surv., 1909, p. 151 for list.

Geologic horizon given in original report: Pleistocene.
Geologic horizon believed to be in this report: Pleistocene.

Four species, *Petricola pholadiformis* Lam., *Donax variabilis* Say, *Drillia thea* Dall, and *Transennella stimpsoni* Dall reported *T. caloosana* Dall—are believed to be exclusively post-Pliocene.

Two species, *Arca limula* var. *platyura* Dall (one valve), and *Corbula caloosae* Dall (one valve) appear to be exclusively Pliocene.

4837.—Two miles southeast of Eau Gallie, on peninsula south of point of Merritt's Island. (See Matson, G. C., and Clapp, F. G., 2nd Ann. Rep't of Fla. Geol. Survey, 1909, p. 151, for list of fossils.)

Geologic horizon given in original report: Pleistocene.
Geologic horizon believed to be in this report: Late Pleistocene.

All species are represented in the recent fauna and one species, *Donax variabilis* Say, appears to be exclusively post-Pliocene and Recent.

NEW LISTS OF SPECIES FROM TWO LOCALITIES

5012.—Seven miles west of Titusville, Brevard Co., Fla.:

Glycymeris pectinata Gmel. (?) (yo.).
Venericardia tridentata Say.
Codakia speciosa Rogers.
Phacoides multilineatus T. and H.
Donax variabilis Say.
Mulinia lateralis Say.

Geologic horizon: Pleistocene.

The larger part of the collection consists of *Donax variabilis* Say.

5017.—Near Michaels marlpit, one mile south of point, Daytona, Volusia Co., Fla., collected by G. C. Matson, 1908.

Acteocina canaliculata (Say).
Olivella mutica (Say).
Alectrion acuta (Say).
Odostomia (Chrysallida) sp. A.
Bittium varium Pfeiffer.

Cerithium muscarum Say (?)
Crepidula plana Say.
Crepidula fornicata (Linné).
Nucula proxima Say.
Arca ponderosa Say.
Arca campechensis Dillwyn.
Arca subsinuata Conrad.
Arca transversa Say (2 forms).
Ostrea virginica Gmelin.
Plicatula gibbosa Lamarck.
Anomia simplex Orbigny.
Venericardia perplana Conrad.
Venericardia tridentata Say.
Chione cancellata Linné.
Chione grus (Holmes).
Anomalocardia caloosana Dall.
Venus campechiensis Gmelin.
Gemma purpurea H. C. Lea.
Parastarte triquetra Conrad.
Tellina tampænsis Conrad.
Semele bellastriata Conrad (?)
Abra æqualis Say (?)
Tagelus divisus Spengler.
Donax variabilis Say.
Mulinia lateralis, var. corbuloides Reeve.
Mulinia lateralis, vars. A. and B.
Rangia cuneata Gray.

Geologic horizon: Pleistocene.

Three species, *Arca campechensis* Dillw., *Gemma purpurea* H. C. Lea, and *Donax variabilis,* appear to be exclusively post-Pliocene.

Arca subsinuata Conrad, hitherto, has been reported only from the Pliocene of the Croatan beds, near New Bern, Craven Co., N. C.

EXPLANATION OF CORRELATION TABLE

In the correlation table given below, the station numbers arranged along the left-hand margin have no reference to the age relation of the contained faunas.

In some cases not all the forms from the locality are considered in the time-range, as the omitted ones are too poorly preserved for specific identification.

The percentage of the fauna from each locality that is believed to exist in the recent fauna is also given. These percentages are not entirely used as a basis for time correlation, as in some cases the number of species from a locality is small and the percentage may not express

CORRELATION TABLE

		Number of species considered	Miocene	Pliocene	Waccamaw (Pliocene)	Caloosahatchee (Pliocene)	Pleistocene	Recent	Miocene—Exclusively	Pliocene—Exclusively	Post-Pliocene—Exclusively	Percentage of recent species
4837,	2 mi. S. E. Eau Gallie	9	4	7	4	7	9	9	0	0	1	100
4865,	Nashua, ¼ mi. S. Type Loc.	28	18	28	23	21	16	16	0	5	0	57
4866,	½ mi. above A. C. L. R. R. bridge	14	6	14	12	13	13	13	0	?	?	93
5003,	4 mi. W. of Eau Gallie	39	15	33	22	31	35	33	0	2	4	85
5008,	5 mi. below Sanford R. R. bridge	18	9	16	12	15	17	17	0	?	2	94
5009,	7 mi. below Sanford R. R. bridge	11	6	11	7	11	11	9	0	0	0	82
5010,	½ mi. S. DeLeon Springs	21	16	20	16	17	14	14	?	1	0	67
5010,	*and* other collections from DeLeon	31	23	30	25	23	20	20	?	2	0	65
5011,	½ mi. N. Orange City R. R. Sta.	6	5	6	6	6	5	5	0	0	0	83
5012,	7 mi. W. of Titusville	4	3	3	2	3	4	3	0	0	1	75
5016,	Well, Kissimmee	12	11	10	10	9	8	8	?	0	0	67
5017,	Daytona	27	12	23	16	21	26	25	0	1	3	93
5019,	¼ mi. S. of Orange City R. R. Sta.	11	11	10	10	8	7	6	?	0	...	55
5143,	Well, Kissimmee	19	10	15	9	13	18	16	0	0	2	84
5144,	Well, on island, L. Tohopekaliga	7	7	6	6	6	4	4	?	0	0	57
5634,	DeLand, lower bed	12	11	11	11	9	10	9	?	0	0	75
5869,	DeLand, upper bed	45	34	42	38	37	29	29	?	3	2	64
6096-7,	½ mi. above A. C. L. R. R. bridge	27	14	27	26	25	26	26	0	0	0	96
7056,	Rose Bluff	18	12	14	13	12	18	17	0	0	2	94

the true condition. In other cases where the fauna is cosmopolitan and the number of species large, the percentages are believed to be helpful.

LIST OF STATIONS WITH AGE ASSIGNMENTS

Pleistocene	4837	(2 mi. S. E. of Eau Gallie) (late).
	5017	(Daytona).
	5012	(Titusville, 7 mi. W.).
	5003	(Eau Gallie, 4 mi. W.).
	5143	(Well, 96 ft. Kissimmee).
	7056	(Rose Bluff).
Late Pliocene or early Pleistocene	4866	(½ mi. above A. C. L. R. R. bridge).
	6096-7	(½ mi. above A. C. L. R. R. bridge).
	5008	(5 mi. below Sanford R. R. bridge).
	5009	(7 mi. below Sanford R. R. bridge).
Pliocene, (Nashua marl)	5011	(½ mi. north of Orange City R. R. Sta.).
	5019	(¼ mi. south of Orange City R. R. Sta.).
	5869	(Upper bed at DeLand).
	5634	(Lower bed at DeLand).
	4865	(Nashua, type locality).
	5010	(DeLeon Springs).
Probably Miocene including some Pliocene	5144	(Well on island in Lake Tohopekaliga).
Miocene, probably including some post-Miocene	5016	(Well, 65 to 100 ft., Kissimmee).

DESCRIPTIONS OF NEW SPECIES

TEREBRA (ACUS) KISSIMMEËNSIS N. SP.

Plate I, Figures 9 and 10

Shell solid, polished, attenuated, conical with about 13 (including 3 nuclear) whorls; nuclear whorls smooth and rounded; axial sculpture on first 4 post-nuclear whorls of about 15 rounded riblets extending unconstricted from suture to suture; later axial sculpture terminating near the center of the whorl as slightly offset, rounded tubercles below which the whorls are somewhat spirally excavated between the central tubercles and another opposing and similar set crowding the suture; spiral sculpture of 3 to 4 narrow impressed lines on earlier whorls, increasing in number on later whorls, all weakly overrunning the axials; suture distinct, narrowly grooved and flexuous; base with two pairs of distinct impressed spiral lines, the upper set being nearer together. Canal short; outer lip missing.

Cotypes (Cat. No. 352280 U. S. N. M.). These measure: the larger specimen (7 whorls),—alt. 12 mm., greatest diameter 3.6 mm.; smaller specimen, alt. 9 mm., greatest diameter 3 mm.

Type locality: Well (depth 65—100 ft.) at Kissimmee, Osceola Co., Fla., Geo. C. Matson, collector, 1908.

Geologic horizon: Probably Miocene.

This species is related to *Terebra (Acus) concava* (Say), but differs from the latter in having no distinct subsutural band, a spiral compression at the anterior part of the whorl, a smaller initial nuclear whorl and fewer revolving striæ on the base.

COLUMBELLA (ALIA) MATSONI N. SP.

Plate I, Figures 3 and 4

Shell small, solid, about six-whorled (tip decollated); spire smooth, elevated, evenly conical; whorls slightly convex, marked by three or four narrow, dim, brownish colored, spiral bands, slightly elevated on the anterior portion of the body whorl; suture somewhat appressed; shoulder of body whorl angled; base and pillar marked by thirteen wide, rounded, raised bands separated by narrow channels, running parallel with and extending nearly to the angled shoulder; aperture moderately wide;

pillar slightly twisted; outer lip, within, with seven denticulated ridges, the posterior one being the largest; inner lip with callus upon which an irregular ridge extends parallel with and close to the outer margin.

Type (U. S. N. M. Cat. No. 352278). This measures: length 10.2 mm.; greatest diameter 4.2 mm.

Type locality: Well (depth 65—100 ft.) at Kissimmee, Osceola Co., Fla., G. C. Matson, collector, 1908. U. S. Geol. Surv. Sta. No. 5016.

Geologic horizon: Probably Miocene.

Discussion: This species is closely related to the northern Miocene form, *Astyris communis* (Conrad); but in the former, the suture is only slightly appressed, the spiral bands on the base more numerous, extending farther up the basal slope. In addition, "*A. communis,* in some specimens, shows distinct traces of narrow color-bands extending across the whorls in a direction nearly parallel with the axis of the shell and slightly flexuous." (See Dall, Wagner Free Inst. Sci., Vol. III, pt. 1, p. 138.)

When the new species is compared with *Astyris profundi* Dall, the suture of the latter is found to be more appressed, the whorls more inflated, and the basal sculpture finer and more narrowly anteriorly confined.

This new species is named in honor of the collector, Mr. George C. Matson.

CAECUM PUTNAMENSIS N. SP.

Plate I, Figures 1 and 2.

Shell small, thin, arched, and slightly tapering; surface almost smooth but under magnification shows faint, irregular annulations and growth lines; posterior end of tube very near the margin, slightly impressed, forming a narrow, low, and inconspicuous ring; plug smooth, hemispherical and extending a little beyond the margin of the tube; mucro small, short, rounded and situated near the margin and a little to the right of the median plane of the shell; anterior end of tube swollen, forming a narrow ring near the margin; anterior margin entire.

Cotypes (Cat. No. U. S. N. M. 352276, spec. A; 352277, spec. B). These measure: length,—specimen A, 2.5; specimen B, 2.3 mm.; diameter of aperture,—specimen A, .6; specimen B, .7 mm.; diameter posterior end,—specimen A, .5; specimen B, .5 mm.

Geologic horizon: Upper Pliocene or lower Pleistocene.

Type locality: One-half mile above A. C. L. R. R. bridge over St. Johns River, Putnam Co., Fla., five feet above high-water level and seven feet below surface. F. G. Clapp, collector, U. S. Geol. Surv., Sta. No. 6096.

Discussion: This species somewhat resembles *Caecum carolinianum* Dall, but differs from the latter in having an anterior ring, a more rounded plug, and lacking longitudinal sculptured striæ. It is closely related to *Caecum chipolanum* Gardner (an unpublished Ms.) species from the Chipola marl member of the Alum Bluff formation, but the latter possesses an anterior furrow and is a much heavier and more tapering shell.

CARDITA (CARDITAMERA) OSCEOLAENSIS N. SP.

Plate I, Figures 11 and 12.

Shell very thin, small, ovate; beaks not prominent, slightly twisted forward, situated at the anterior third of the valves; lunule long, moderately impressed; anterior side and middle of valves rounded; posterior side steeply sloping; posterior dorsal margin nearly straight, sloping at a low angle; anterior dorsal margin sloping and slightly undulated; posterior margin nearly straight, truncating the end, making nearly a right-angle with the dorsal margin and a rounded edge with the ventral; anterior margin rounded; ventral margin arcuate. Shell sculptured radially by 20, rather low, rounded ribs, nodulous about the beaks and roughened distally by transverse ridges or imbricated growth lines. Whole surface sculptured radially by fine, indistinct lines and transversely by rather fine imbricated growth structure. Inter-radial spaces about one and one-half as wide as ribs on the anterior and center of the disk, but narrower at posterior angle where ribs widen out. Lateral teeth small; anterior cardinal slender and prominent. Interior surface markedly fluted, reversing external sculpture and showing a pecten-like appearance.

Type (Cat. No. 352275 U. S. N. M.); This measures: length of left valve 12.4 mm.; height 8.5 mm.; diameter (double) 6 mm.

Geologic horizon: Probably Miocene.

Locality: Well at Kissimmee, Osceola Co., Fla., (depth 65—100 ft.). G. C. Matson, collector, 1908.

Discussion: The thinness of the shell approaches *C. catharia* Dall, but in the new species the posterior angled edge is less drawn out, the disk is more rounded and the shell more nearly equilateral. The shape of the shell resembles *C. vaughani* Dall, but the latter is much heavier and more robust in every way. I am unable to find a very close relative to the described species.

EXPLANATION OF PLATE I

Fig. 1. Cæcum putnamensis n. sp. Cotype, (x 10). U. S. N. M. Cat. No. 352277.
Fig. 2. Cæcum putnamensis n. sp. Cotype, (x 10). U. S. N. M. Cat. No. 352276.
Fig. 3. Columbella (Alia) matsoni n. sp. Ventral view, Type (x 3).
Fig. 4. Columbella (Alia) matsoni n. sp. Dorsal view, Type (x 3). Nucleus restored.
Fig. 5. Corbula inæqualis Say, var. A. Exterior of right valve (x 2). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352286.
Fig. 6. Corbula inæqualis Say, var. A. Exterior of left valve of another specimen (x 2). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352286.
Fig. 7. Corbula inæqualis Say, var. B. Exterior of left valve (x 2). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352287.
Fig. 8. Corbula inæqualis Say, var. B. Exterior of right valve (x 2). Station 5869, (stratum No. 3). U. S. N. M. Cat. No. 352287.
Fig. 9. Terebra (Acus) kissimmeënsis n. sp. Larger cotype (x 3).
Fig. 10. Terebra (Acus) kissimmeënsis n. sp. Smaller cotype (x 5).
Fig. 11. Cardita (Carditamera) osceolaënsis n. sp. Exterior of left valve. Type (x 3).
Fig. 12. Cardita (Carditamera) osceolaënsis n. sp. Interior of left valve. Type (x 3).
Fig. 13. Arca transversa Say. Light form. Exterior of left valve (x 1½). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352281.
Fig. 14. Arca transversa Say. Light form. Right valve of another specimen (x 1½). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352281.

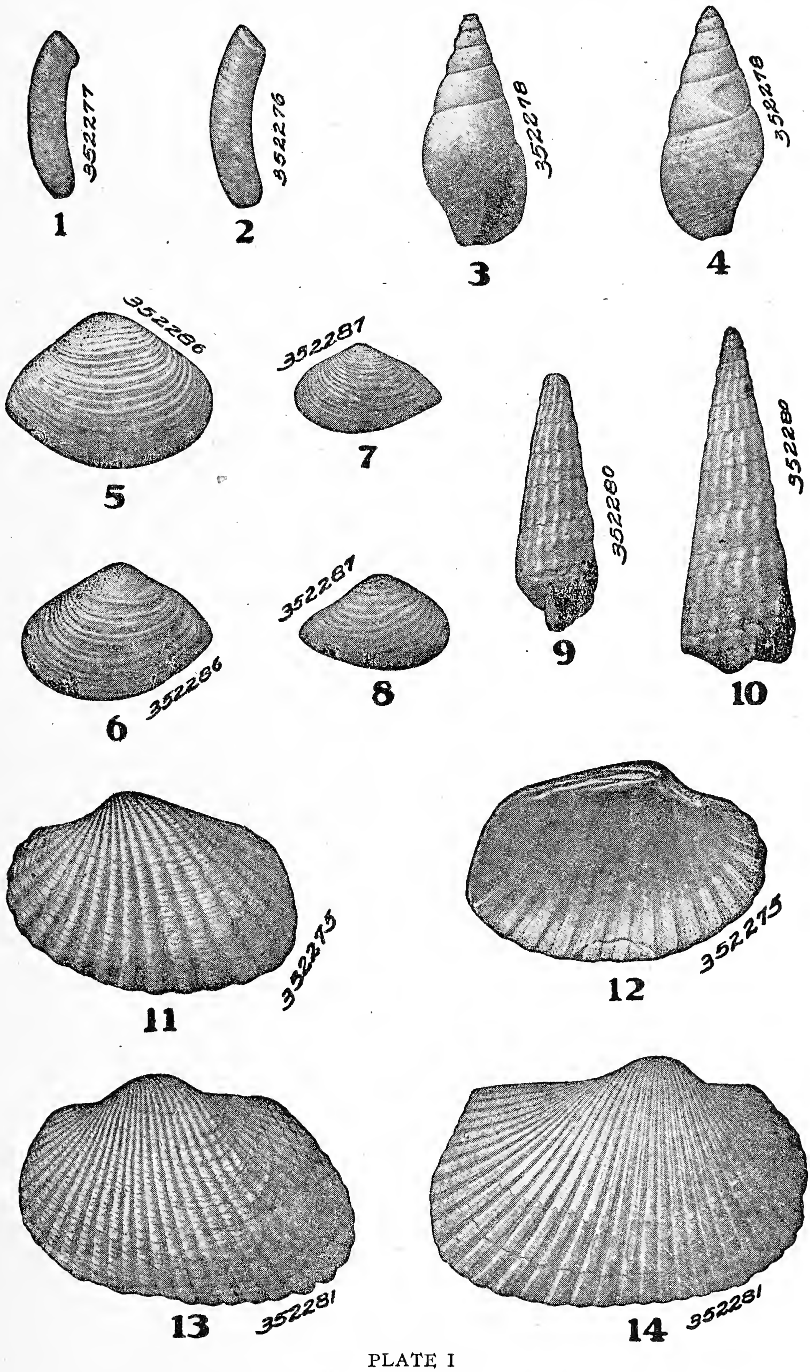
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PLATE I

Plate II.

Figs. 1 & 2. Mulinia contracta (Conrad). Left valve (x 1½). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352283.

Figs. 3 & 4. Mulinia sp. near M. caloosaënsis Dall. Left valve (x 1½). Station 4865, ¼ mile south of Nashua, Fla. U. S. N. M. Cat. No. 352284.

Figs. 5 & 6. Mulinia lateralis Say. Heavy form. Left valve (x 1½). Station 5634, DeLand, Fla., (stratum No. 1). U. S. N. M. Cat. No. 352285.

Figs. 7 & 8. Mulinia lateralis Say. Long form. Left valve (x 1½). Station 5869, DeLand, Fla., (stratum No. 3). U. S. N. M. Cat. No. 352282.

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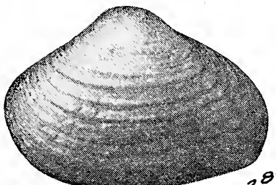

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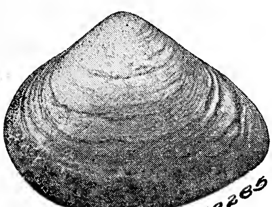

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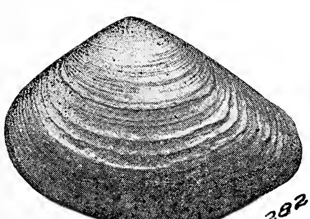

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PLATE II

A

PRELIMINARY REPORT

ON THE

CLAYS OF FLORIDA

(EXCLUSIVE OF FULLER'S EARTH)

BY

OLIN G. BELL

LETTER OF TRANSMITTAL

MR. HERMAN GUNTER, *State Geologist,*
Tallahassee, Florida.

Sir:—I herewith transmit my manuscript and illustrations of A Preliminary Report on the Clays of Florida. The field and laboratory work have been done and the report prepared in accordance with our agreement of February 6, 1922.

Permit me to express my appreciation of the interest you have taken in this work during its various stages and the assistance you have given in its prosecution.

Very respectfully,

OLIN G. BELL.

Cornell University, Ithaca, New York, November 12, 1923.

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LIST OF ILLUSTRATIONS—CONTINUED

INTRODUCTION.

SCOPE OF THIS REPORT

In this investigation no attempt has been made to cover completely the clay deposits of the entire State of Florida. It is intended to be only a preliminary report which will make available at an early date data concerning the clays within reach of transportation. It will, moreover, furnish a basis or foundation upon which further and more extensive work on the clay resources of the State can be based as it becomes expedient to do so.

This report, therefore, considers only the clay deposits known at the time the field work was carried on and situated not more than two miles from water or rail transportation.

Unless a clay deposit is of very exceptional quality, it is not probable that it will be developed within the next few years if more than a mile or so from a railway. No definite distance from transportation, however, can be placed as a limit for workable deposits. The quality of the clay, availability and cost of fuel, labor, cost of mining or manufacturing, cost of equipment, proximity to market, prevailing market price, distributing facilities and numerous other local factors determine whether or not a clay deposit can be profitably worked. Deposits of clay not within an economic distance from transportation are potential sources of supply and can be considered only as reserves. As general development proceeds in the State these deposits will become useful.

Clay deposits underlying a great thickness of overburden are likewise not considered in this report. Here again the conditions mentioned above apply. The greater the overburden which must be removed the greater the cost of production. Clays which are now at too great a depth to be profitably worked may become workable at some future time.

In most cases the thickness and extent of a clay deposit were not given any further consideration than to determine whether or not sufficient clay was available to supply an average demand for a reasonable period of time. In many deposits enough clay was seen to be at hand to supply an average brick plant for more than thirty years. A dependable estimate is that 750,000 bricks can be made from an acre foot, (43,-560 cubic feet,) of clay. A plant of 12,000,000 annual capacity would utilize 15 acre-feet of clay per year. The thickness and extent of a clay deposit and the cost of acquiring the property are factors, therefore,

which should be given thorough consideration by a prospective manufacturer.

The aim of this report is to guide the manufacturer to deposits worthy of his notice and to furnish owners of such clay deposits knowledge of their occurrence, properties, and usefulness and it is hoped that this work will be of some assistance in furthering the development of the clay industries of Florida.

The general geology, classification, mineralogy, chemical and physical properties, and uses of clays are briefly discussed in this report. Much has already been published on these topics and the discussion which follows is by no means exhaustive. It summarizes the more important facts that have been brought out by previous investigators. This is done to answer numerous inquiries continuously being received by the Survey regarding the common properties of clays, and also to enable those people who have neither time nor facilities to consult the other publications to have the benefit of this knowledge which may facilitate their use of the data bearing on the Florida clays. Adequate footnote references are made to other writers so that readers may consult the principal papers previously published dealing with clays.

A discussion of the methods of manufacture of clay products, descriptions of the individual brick plants and numerous other sections have been omitted in order to conserve space. Numerous photographs, however, have been used to show the types of machinery employed, types of kilns in operation, methods of clay mining, and general plan and arrangements of plants.

Fuller's earth, a clay with special properties but little or no plasticity, has been discussed at considerable length in previous reports of the Survey, particularly the Second and Sixth Annual Reports, and the time and funds available did not permit a further treatment of it in the present paper.

FIELD WORK

The field work was carried on during the season of 1922. At this time all accessible clay deposits of which the State Geological Survey had any knowledge were visited. Inquiries made in each locality during the progress of the work brought many additional deposits to notice. In each case the deposit was examined as thoroughly as time permitted and if the clay seemed promising at all a representative sample was

taken for laboratory tests. The tests were made by the writer at Cornell University, Ithaca, New York. In a few cases samples of clay from deposits not known at the time of the field work were later sent to the testing laboratory.

PREVIOUS WORK ON FLORIDA CLAYS

Much work has previously been done on the clays of Florida, particularly on the sedimentary kaolins of Putnam and Lake counties and on the fuller's earth of Gadsden and Manatee counties. Most of this material has been published by the United States Geological Survey, but some has appeared in the Annual Reports of the State Geologist of Florida and some in scientific journals. The literature dealing with the clays of the State has been freely used. Credit for such information has been given in the footnote references in each case.

ACKNOWLEDGMENTS

The writer desires to express his deep appreciation of the liberal and patient help accorded him by numerous individuals during the progress of this work. Dr. H. Ries kindly granted the use of the clay testing laboratory at Cornell University, and has given the author many helpful suggestions, Mr. Herman Gunter, State Geologist, rendered much assistance in planning and carrying out the field work. Mr. T. C. Adams, a graduate student at Cornell University, kindly permitted the use of a chart which appears as Fig. 1. A very great number of people in the various localities rendered invaluable aid, and many gave liberally of their time, in guiding and directing the party to the more important clay deposits. Among these may be mentioned Mr. J. E. Worthington of Lake Wales, Mayor F. D. Cosner and Mr. C. B. Taylor of Dade City, Mr. W. A. Fulton of Brooksville, Dr. T. S. Kennedy of Williston, Mr. W. B. Powell of Tavares, Secretary of the Lake County Chamber of Commerce, Mayor C. A. Vaughn and Mr. Allen Strait of Umatilla, Mr. C. H. Tedder, Secretary of the Chamber of Commerce, Live Oak, Mr. H. D. Mendenhall, Consulting Engineer, of Lakeland, and numerous others. The brick and pottery manufacturers and superintendents of clay mining plants were uniformly courteous and generous in their assistance while the party was visiting their plants.

CHAPTER I

GENERAL GEOLOGY OF CLAYS

DEFINITION

The general usage of the term clay is a very broad one and includes a large variety of substances. This liberal usage of the term has developed as a result of clay being one of the most abundant natural products. It is found in some form in practically every locality and is used for a great variety of purposes. No one definition of clay, therefore, can satisfactorily fulfill all requirements. This is partly due to the fact that the present knowledge of clays is far from complete, but more especially due to the fact that clays vary greatly in their properties and uses. No two clays are exactly alike.

In any sense of the term clay is a substance occurring in nature which is plastic when wet, capable of being molded, preserves its shape upon being dried, and changes to a hard rock-like substance on being fired. Ries[1] defines clay "as an earthy material occurring in nature whose prominent property is plasticity when wet." Merrill[2] describes clay "as a whole, as heterogeneous aggregates of hydrous aluminous silicates, free silica, and ever-varying quantities of free iron oxides and calcium magnesium carbonates, all in finely comminuted condition. Orton[3] says: "Strictly speaking, however, the term applies to a single mineral, viz., silicate of alumina or kaolinite." Wheeler[4] says: "The scientific definition of the term clay is a more or less pure variety of the mineral kaolinite, the hydrous silicate of alumina." He also gives the following as the popular definition of a clay: "Clay is an earthy material that becomes plastic when wet."

Thus it is seen that the principal definitions take two forms, viz., those based upon the property of plasticity and those based upon the mineral composition. Both of these are correct in that all clays are

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 1, 1908.
[2]Merrill, G. P., The Non-Metallic Minerals, p. 221, 1910.
[3]Orton, E., The Clays of Ohio, Their Origin, Composition and Varieties. Ohio Geol. Survey, VII, Part I, p. 46, 1893.
[4]Wheeler, H. A., Clay Deposits, Mo. Geol. Survey, XI, p. 17, 1896.

plastic to a greater or less degree and probably all contain some form of hydrous aluminum silicate, in widely varying quantities.*

ORIGIN

A clay is in all cases a secondary product resulting from the decomposition and disintegration of pre-existing rock. If the clay remains in the space formerly occupied by the parent rock it is said to be residual. If, however, the clay is transported, either by wind or water, and then deposited it is termed a transported or sedimentary clay.

The breaking down of one rock and the resultant formation of clay is one of the processes of rock weathering. This includes both chemical action (decomposition) and mechanical action (disintegration) which are often carried on at the same time and are very closely related. Weathering takes place chiefly through such atmospheric agencies as rain, frost, wind, changes in temperature, through organic agencies as plants and animals, and through the action of atmospheric gases.

Igneous rocks are the primary sources of all other rocks and are then the original sources of all clays. Limestone or shale residual clays are only indirectly derived from igneous rocks and have previously gone through one or more processes of weathering and sedimentation. Rocks containing feldspar may weather into clay. In fact, it was formerly believed that all clay resulted from the weathering of feldspathic rocks. Ries[1] has pointed out that "there are some rock species, however, that contain no feldspar (such as serpentine), and others with very little (as some gabbros), which, on weathering, produce some of the most plastic clays known." In the process of weathering the more insoluble portions, such as some of the aluminum silicates, accumulate and the more soluble constituents, as lime, magnesia, potash, soda, and sometimes silica, are carried away.

During the weathering process the clay which consists of very fine particles may be left intimately mixed with larger particles of sand and other material. If this mixture is carried away by the action of running water a separation of the clay from the coarser material may result. Such a separation has often been the cause of the formation of large bodies

*Soil investigators have still other definitions for clay based on fineness of grain rather than plasticity or chemical composition, one being all soil particles less than .005 mm. in diameter, and another that part of the soil which will remain suspended in an 8-inch column of water for 24 hours. Slightly coarser and non-plastic material is distinguished as silt. (See Hilgard, Soils, pp. 57-62, 83-85, 1906.) H. G.

of clay free from sand. In other cases velocity and current conditions may be such as to transport and deposit some sand with the clay resulting in the formation of a sandy clay.

After a clay deposit has been formed it may be modified in various ways. For example, the more soluble elements may be leached from it and carried away by circulating waters. Other mineral matter may, under certain conditions, be carried in and deposited by the same process.

GEOLOGIC TYPES OF DEPOSITS

There are in general two important types of clay deposits. One is termed residual because it is the residue resulting from the weathering or decomposition of a rock in place. The other is termed sedimentary or transported as the material has been transported from a former position and deposited as sediment by the action of water or wind. It is not always possible to distinguish these two types in the hand specimen. In Florida it is also sometimes difficult to apply the fundamental distinctions in the field as sufficient evidence is often inaccessible.

A residual clay is found where the decay of the parent rock has gone on without interruption for a long period of time and where the resulting products have not been carried away by erosion. Such deposits usually take the form of a clay mantle or covering which is co-extensive with the parent rock. Their thickness is often very irregular depending upon the depth to which weathering has proceeded and the amount of erosion which has followed.

Residual clays may result from a variety of sedimentary, igneous or metamorphic rocks. The most important residual clays are derived from the decomposition of rocks high in feldspathic constituents. Such clays, if high grade, usually must be purified by washing in order to remove undesirable ingredients as quartz, mica, etc. They are frequently highly colored by iron compounds and these are not completely removable.

Deposits of residual clay are usually characterized by a gradual passage from pure clay at or near the surface to the unaffected parent rock below. In this passage from the surface downward first a zone of fully formed clay is encountered which gradually passes into a zone of badly decayed angular rock fragments, then into a zone of only partially altered fragments and finally into the fresh unaltered parent rock. There is no sharp line of demarcation or contact between the zones above men-

tioned.[1] This, however, is not the case in clays residual from limestone.

In limestone residual clays, on the other hand, there is a sudden change from clay to the limestone parent rock below. Most surface water, particularly rainwater, carries dissolved in it some carbon dioxide gas, (CO_2) resulting in the formation of an acid, (carbonic acid, H_2CO_3), which attacks the calcium carbonate of the limestone forming a compound, (calcium bicarbonate, $Ca(HCO_3)_2$), which is soluble in water. This process in Florida and elsewhere is greatly augmented by the addition of organic acids furnished by plants and decaying vegetable material. Thus limestone is decomposed and the soluble portion carried away in solution. Most limestones, however, have varying amounts of impurities, such as clay substance, which is not affected by the weak acids and is insoluble in water. It therefore remains as residual clay when the limestone is dissolved. Thus when the decomposition of the limestone has occurred to any depth there is a sharp contact between the clay and the underlying limestone because this change is not due to a gradual breaking down of the minerals in the rocks, as in the case of the feldspathic rocks.

Sedimentary clays are those which have been transported by the action of water or wind from their point of origin and deposited elsewhere in the form of stratified beds. Thus clay particles are swept from the land surface in the process of erosion and carried to lakes, estuaries, or the sea, etc., where they settle to the bottom of the quiet water as sediments. Such deposits may have no genetic relationship with the beds below or above. Deposits of sedimentary clay are sometimes of great thickness, but are more frequently rather thin. They may be of great purity or they may be accompanied by much impure material as mineral fragments (sand, mica flakes, etc.) or vegetable matter. These clays may often have a great lateral extent or they may be confined within a small area. They are at times interbedded with other sediments and may even be crossbedded. Some deposits exhibit marked irregularities of thickness, becoming thicker in one place and thinning out in

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[1]For a complete discussion of the processes involved in the formation of residual clay see any of the following: Buckman, H. O., The Chemical and Physical Processes Involved in the Formation of Residual Clay, Trans. Am. Ceramic. Soc., Vol. 13, p. 336, 1911.

Merrill, G. P., Rocks, Rock Weathering and Soils, p. 289, 1913.

Ries, H., Clays, Their Occurrence, Properties and Uses, p. 7, 1908.

another. Likewise distinct changes in the character of the clay may occur from place to place in the same bed.

There are several forms of sedimentary clay deposits based upon the conditions of sedimentation. The following with the exception of the last two, glacial and aeolian clays, are all found in Florida.

Marine Clays—Fresh water in rivers, etc., may contain much clay substance, consisting of the very finest and lightest particles, which it carries in suspension. This acts as a solution of clay in water. When this fresh water becomes mixed with sea water the clay flocculates and is deposited on the sea floor, or, as is frequently the case, in estuaries or lagoons along the coast. Extensive clay deposits are frequently thus found.

Flood-Plain Clays—Streams carrying clay material in suspension or rolling it along on the stream floor often deposit much of it in the adjacent lowlands during periods of flood. Subsequent overflows deposit additional layers. Extensive flood-plain deposits are often formed in this manner along the larger streams and in their deltas. Flood-plain clays are extremely variable in their nature and are often calcareous or sandy.

Lacustrine Clays—Clay material carried by streams into lakes or ponds gradually settles to the bottom of the quiet water to form a deposit of clay on the lake floor. Such clays may be of great purity or they may be mixed with a great amount of sand or other impurities.

Glacial Clays—These are sometimes termed till or bowlder clay. These are deposits, which are of heterogeneous character and usually impure, formed by the grinding of rocks or rock fragments by glacial action and deposited by the ice as it melted or by the resulting water in the redeposition of the material. Deposits of this type are only found in glaciated regions. None exist in Florida.

Aeolian Clays—Deposits of clay formed by the action of the wind are termed aeolian clays. In arid regions clay in the form of dust is blown about and sometimes accumulates in extensive beds. Some loess clays are believed to have been deposited in this manner. No such clays are known in Florida.

CHAPTER II

CLASSIFICATION OF CLAYS

Clays may be classified in a variety of ways, according to their origin, mode of occurrence, properties, or uses. No classification yet proposed, however, has satisfactorily treated such a diversity of factors. A classification based upon the origin would be of special interest to the geologist, while a ceramist would be more keenly interested in one based upon their physical properties. A classification based upon the uses of clays is probably the least satisfactory of any due to the fact that there is a very great range in the kind of clay used for any one purpose, and that one clay may be used for several different purposes.

In the past three decades no less than nine[1] separate classifications have appeared in the literature dealing with clays. While none of these are satisfactory in every respect, three of them deserve careful consideration.

Ries's[2] classification is based primarily on the geological occurrence and secondarily on the firing qualities of clays. It follows:

A. Residual clays. (By decomposition of rocks in situ.)
- I. Kaolins or china clays. White-burning.
  - (a) Veins, derived from pegmatite.
  - (b) Blankets, deposits, derived from extensive areas of igneous or metamorphic rocks.
  - (c) Pockets in limestones, as indianaite.
- II. Red-burning residuals, derived from different kinds of rock.

B. Colluvial clays, representing deposits formed by wash from the foregoing and of either refractory or non-refractory character.

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[1]Orton, E., Clays of Ohio, Ohio Geol. Survey, VII, p. 52, 1893.
Wheeler, H. A., Clay Deposits, Missouri Geol. Survey, XI, p. 25, 1896.
Ladd, G. E., Preliminary Report on the Clays of Georgia, Georgia Geol. Survey, Bull. 6A, p. 12, 1898.
Buckley, E. R., The Clays and Clay Industries of Wisconsin, Wis. Geol. Survey Bull. 7, Part I, p. 14, 1901.
Orton, E., Jr., Quoted by Beyer, S. W., and Williams, I. A., Technology of Clays, Iowa Geol. Survey, Vol. XIV, p. 40, 1903.
Grimsley, G. P., Clays, Limestones, and Cements, West Va. Geol. Survey, Vol. III, p. 70, 1905.
Ries, H., Clays, Their Occurrence, Properties and Uses, p. 27, 1908.
Grout, Frank F., and Soper, E. K., Preliminary Report on the Clays and Shales of Minnesota, Minn. Geol. Survey, Bull. II, p. 18, 1914.
Parmelee, C. W., Further Investigation of Illinois Fire Clays, Bull. 38, Ill. Geol. Survey, p. 10, 1921.

[2]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 27, 1908.

C. Transported clays.
- I. Deposited in water.
  - (a) Marine clays or shales. Deposits of great extent.
    White-burning clays. Ball clays.
    Fire-clays or shales. Buff-burning.
    Impure clays or shales { Calcareous. / Non-calcareous.
  - (b) Lacustrine clays. (Deposited in lakes or swamps.)
    Fire-clays or shales.
    Impure clays or shales, red-burning.
    Calcareous clays, usually of surface character.
  - (c) Flood-plain clays.
    Usually impure and sandy.
  - (d) Estuarine clays. (Deposited in estuaries.) Mostly impure and finely laminated.
- II. Glacial clays, found in the drift, and often stony. May be either red or cream-burning.
- III. Wind-formed deposits. (Some loess.)
- IV. Chemical deposits. (Some flint clays.)
  - (a) Replacement deposits.
  - (b) Chemical deposits.

Grout and Soper[1] have used the physical properties as a basis of classification and refractoriness the basis of subdivision. It is as follows:

	Uses.
I. Refractory (above cone 27).	
(a) Earthy, usually residual, non-plastic	China clay.
(b) Plastic	Ball clay.
(c) Flint-like, non-plastic	Fire clay.
II. Semi-refractory (above cone 10).	
(a) Safely vitrifying.	
Red burning	Sewer Pipe. Paving Brick.
Buff or Cream-burning	Stoneware.
(b) Rapidly fusing	Low-grade fire clay.
III. Non-refractory (below cone 10).	
(a) Safely vitrifying.	
Red-burning	Drain tile. Foundation brick.
Buff or cream-burning	Vitrified brick. Fountain and sewer brick.
(b) Rapidly fusing	Common brick.

Note—Subdivisions of II and III may be made on the basis of degree of plasticity, or some other physical character.

Recently Parmelee[2] has proposed a classification which is based on the uses of clays according to their physical properties. Parmelee points

[1]Grout, Frank F., and Soper, E. K., Preliminary Report on the Clays and Shales of Minnesota, Minn. Geol. Survey, Bull. 11, p. 18, 1914.
[2]Parmelee, C. W., Further Investigation of Illinois Fire Clay, Bull. 38, Ill. Geol. Survey, p. 10, 1921.

out that this classification treats only the uses of clays for burned products and such other uses, as paper and cloth filler, pigments, manufacture of Portland cement, etc., are not considered. He further states that: "This does not exclude clays from uses not specified. For example, a superior fire clay may be suited for the manufacture of common brick. Its primary usefulness, however, may be regarded as for fire brick since it will be most valuable manufactured into that product."

Parmelee[1] states that a revised form of this classification is to appear in an early issue of the *Journal of the American Ceramic Society,* and the classification as first published will, therefore, not be quoted here.

[1]Parmelee, C. W., private communication.

CHAPTER III

MINERALOGY AND CHEMICAL PROPERTIES OF CLAYS

MINERALS IN UNBURNED CLAYS

Clay is composed essentially of a hydrous aluminum silicate, usually in the form of kaolinite with perhaps some of the minerals closely related to it, varying amounts of colloidal matter, of either organic or mineral character, and fragments of a great many different minerals representing chemically oxides, carbonates, silicates, hydroxides, etc. It will be seen then that clays may vary widely in their mineral and chemical compositions.

Kaolinite was formerly believed to be the basis of all clay, but this view is now known to be erroneous. It is, however, very abundant in many clays. In one hundred and twelve samples of unburned clay examined miroscopically by Somers[1] he reports kaolinite as scarce in only fourteen. It is a hydrous aluminum silicate represented by the formula Al_2O_3, $2SiO_2$, and is composed then of 46.3 per cent silica (SiO_2), 39.8 per cent alumina (Al_2O_3), and 13.9 per cent water (H_2O). It is insoluble in hydrochloric acid and slowly soluble in hot sulphuric acid. It is always a secondary product and results from the alteration of other

[1]Somers, R. E., Microscopic Study of Clays, in U. S. Geol. Survey Bull. 708, p. 292, 1922.

aluminous silicates, as feldspar. It is white in color, slightly plastic, has a hardness of 2-2.5 and a specific gravity of 2.2-2.6.

Crystals of kaolinite are of very rare occurrence in clays but have been described by several writers.[2] According to Hickling[3] the kaolinite occurs in irregularly hexagonal prisms with rough faces which show strong transverse striations that correspond to the basal cleavage.

There are several minerals very closely related to kaolinite. These are all hydrous aluminum silicates, but it is doubtful if all commonly placed in this class are really distinct species. They sometimes occur in crystalline form, but more frequently occur in the amorphous condition. These minerals are halloysite, indianaite, pholerite, rectorite, newtonite, allophane, cimolite, montmorillonite, pyrophyllite, collyrite, and schrötterite. Some of these minerals can be identified by their optical properties.[1]

There are many other minerals not related to kaolinite which are often found in clays and do not decompose readily. They may be briefly treated as follows:

Quartz—SiO_2. This mineral is found in practically every clay, though usually in very fine grains and sometimes in very small quantities. It may also occur in the amorphous form. In residual clays the grains are usually angular while in the sedimentary clays they are somewhat rounded, due to the rolling and tossing about they have received by the water action. In quantity in clays quartz ranges from less than one per cent in some white sedimentary clays to more than eighty per cent in some other clays. Quartz fuses at 1830° C. (cone 35),[2] but in the presence of other minerals which act as a flux it may soften at a lower temperature. In clays it affects the fusibility, shrinkage, plasticity, and bonding strength, depending upon the amount and texture of the quartz present.

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[2]Dick, M., Mining Magazine, Vol. VIII, p. 15, 1876.
Reusch, H., Jahrb. f. Min., Vol. II, p. 70, 1887.
Johnson, S. W., and Blake, J. M., American Journal of Science, II, Vol. XLIII, p. 351. 1867.

[3]Hickling, G., China Clay; Its Nature and Origin, Trans. Inst. Min. Eng. (England), Vol. 36, 1908-9.

[1]Larsen, E. S., The Microscopic Determination of the Non-opaque Minerals, U. S. Geol. Survey Bull. 679, 1921.

[2]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 55, 1908.

Feldspar—This mineral as a rule is not abundant in clays, though it decomposes more readily than quartz and thus usually occurs in smaller grains. Feldspar occurs in several forms which differ slightly in their chemical compositions. While these different species of feldspar vary to some extent in their melting points it may be said that feldspar fuses at about 1310° C. (cone 9)[3], although in the presence of alkalies this temperature is much lower. Clarke[4] gives the melting point of feldspar as ranging from 1265° to 1550° C. He points out, however, that these observations were made upon artificial preparations of great purity.

COMPOSITION OF FELDSPARS[1]

Feldspar Species	*Chemical Composition*				
	SiO_2	Al_2O_3	K_2O	Na_2O	CaO
Orthoclase	64.70	18.40	16.90	0.00	0.00
Albite	68.00	20.00	00.00	12.00	12.00
Oligoclase	62.00	24.00	00.00	9.00	5.00
Labradorite	53.00	30.00	00.00	4.00	13.00
Anorthite	43.00	37.00	00.00	0.00	20.00

Mica—This is another mineral which occurs in the form of several different species which likewise have a variation in their different compositions. Mica occurs in most clays and is very difficult to remove. In washing, on account of its light scaly character, it floats off with the clay particles. Mica acts as a flux in clays at a high temperature. It is abundant in the clays of Florida. Few clays of the State are free from it, while in some of those in the western counties it is present in large quantities. The chief mica is muscovite because it is less easily weathered.

Hydromica—Hydromica is, according to Somers[2] a distinctly micaceous mineral which represents a transition stage of weathering between sericite and kaolinite, with kaolinite as the final product. Somers reports hydromica as scarce in only twenty-two and unidentifiable in twelve of the clays examined by him. Hydromica is peculiarly abundant in many clays.

[3]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 55, 1908.
[4]Clarke, F. W., Data of Geochemistry, U. S. Geol. Survey Bull. 695, p. 360, 1920.
[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 55, 1908.
[2]Somers, R. E., Microscopic Study of Clays, in U. S. Geol. Survey, Bull. 708, p. 296, 1922.

Limonite—This is an iron mineral represented by the formula $2Fe_2O_3$, $3H_2O$. Its occurrence in clays is widespread and in a variety of forms. When present in a finely divided state it gives to the clay a yellowish or brownish color. It is always a secondary product resulting from the alteration of other minerals. It may occur in clays disseminated in fine grains, as a coating or thin film covering the clay particles, as concretions, or limonitic crusts and layers. It exerts a strong coloring and fluxing action in the burning process, if abundant and uniformly distributed. The presence of a very small per cent may produce a noticeable coloring effect and is therefore an injurious ingredient of a clay desired for whiteware. If limonite occurs in small lumps and these are not finely crushed, they appear in the burned product as unsightly black splotches. Limonite concretions are very common in many Florida clays and limonite or other hydrous iron oxides in other forms is widely distributed over the State.

Hematite—Fe_2O_3. This is another iron mineral which may be found in clays, but as it alters to limonite easily on being exposed to moisture and air, it is not so common. Its effect in clays is similar to that of limonite.

Magnetite—Fe_3O_4. A magnetic ore found in some clays as black magnetic grains. It is not, however, a common constituent of clays.

Siderite—$FeCO_3$. This is the iron carbonate which occurs in some clays and shales as concretionary masses or as disseminations. It changes to limonite if exposed to the weathering agencies. If in a finely divided state and evenly distributed through the clay, it is said to give a blue or slate-gray color to the raw clay. In burning the carbon dioxide, (CO_2), is driven off. The resulting effect is probably similar to that of limonite.

Pyrite—FeS_2. This mineral, the iron sulphide, is common in some clays and was noted in some of the Florida clays. It is pale or brassy yellow in color, has a metallic lustre, and occurs as small cubical grains or as nodular lumps. Pyrite is an injurious ingredient as it not only has an effect similar to that of the other iron minerals but the sulphur dioxide (SO_2) may, in burning, unite with steam to form sulphuric acid (H_2SO_4), which in turn may combine with calcium or magnesium compounds to form soluble salts. These may cause a white efflorescence or coating on the ware. If the pyrite occurs in large masses it may be screened or picked out by hand. Pyrite is sometimes an impurity in coal

and when such coal is used as fuel in firing clay products it may cause the same injurious scumming effects as when it is an ingredient of the clay.

Calcite—$CaCO_3$. The presence of this mineral in clays can be easily detected by the application of a few drops of hydrochloric acid which causes the calcite to effervesce briskly. Calcite is quite abundant in some clays and may occur as disseminations, as concretions, or as fragments of limestone. These larger pieces can be separated by hand in mining. Calcite acts as a flux in burning and if present in fine lumps is converted into lime (CaO) which slakes upon being exposed to air and causes the ware to crumble unless hard-fired. If the calcite is present in a finely divided state and evenly distributed through the clay it has no especial injurious effect. Some of the Florida clays are quite calcareous. At higher temperatures the lime resulting from the burning of calcite will unite with the other elements of the clay, especially the alumina and silica, giving a reaction which has a marked effect on the color as well as the fusibility of the clay. If the lime be in excess of the iron, when iron is present, it has a tendency to give the ware a buff color. Ries[1] states that this effect is most marked when the percentage of lime is three times that of iron.

Gypsum—$CaSO_4, 2H_2O$. This mineral, the calcium sulphate, is not widely distributed in clays, but in some deposits it occurs abundantly. It is regarded as an injurious ingredient when present. Ries[2] says: "The effect of gypsum on clay is that of a flux, especially if the brick is burned to vitrification, but if the clay is not burned sufficiently hard to drive off the sulphuric acid which the gypsum contains combined with the lime, then soluble sulphates may be left in the clay, which will be brought to the surface of the brick where they cause an unsightly white coating upon evaporation of the moisture." Gypsum has a pearly lustre and occurs in plate-like crystals or in fibrous form and exhibits no effervescence when acid is applied. It may be secondary in origin in clays and is formed by the action of sulphuric acid upon calcium carbonate. Gypsum specks in burned clay do not cause the ware to slake as is the case when calcite is present. Ries[3] states that he has

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 87, 1908.

[2]Ries, H., Clays of Maryland, Md. Geol. Survey, Special Publication, Vol. IV, Part III, p. 225, 1902.

[3]Ries, H., Private Communication.

collected clays in Florida that had crystals of selenite (one form of gypsum) as much as a half an inch in diameter.

Rutile—TiO_2. This mineral is probably widely distributed in clays, usually in small amounts. Few attempts have been made to identify it in clays. It rarely occurs in large quantities. Somers[4] reports rutile as unidentifiable in three of the one hundred and twelve clays examined miroscopically by him, moderate in three, scarce in fifty-three, common in twenty, and abundant in thirty-three. Its effect is negligible except in white-burning clays. It usually occurs in microscopic grains.

Ilmenite—$TiFe_2O_3$. It is not definitely known that this mineral occurs in clays, but its occurrence is probable in those clays which have been derived from soda-rich and basic eruptive rocks. Ilmenite is a constituent of some of the sands along the east coast of Florida and its presence is to be expected in some of the clays of that region. Its effect is perhaps similar to that of rutile.

Glauconite—This mineral, often called greensand, is a hydrated silicate of ferric iron and potassium with aluminum and water in variable proportions, and usually mixed with other minerals. It is easily fusible and hence a high percentage of it is not desirable. It is olive to grayish-green in color. It occurs in many of the clays of the Atlantic coastal plain region and has been reported in clays in New Jersey[1], Maryland[2], and Georgia[3].

Chlorite—This term is applied to a group of secondary minerals which are hydrous aluminum silicates with ferrous iron and magnesium. Ferric iron may sometimes be present. It is found in small quantities in some clays. Its presence in the Cretaceous clays of Georgia[4] and the Leda clays of Canada[5] has been reported.

Dolomite—$CaMg\ (CO_3)_2$. Dolomite is very similar in composition and properties to calcite. Alone it is highly refractory, but acts as a flux with other minerals. Dolomite is common in some of the clays of the Manatee River region.

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[4]Somers, R. E., Microscopic Study of Clays, in U. S. Geol. Survey Bull. 708, p. 292, 1922.

[1]New Jersey Geol. Survey, Final Report, VI, p. 46, 1904.

[2]Maryland Geol. Survey, Eocene, p. 52, 1901.

[3]Veatch, Otto, Clay Deposits of Georgia, Georgia Geol. Survey, Bull. 18, p. 41, 1909.

[4]Ladd, G. E., American Geologist, Vol. XXIII, p. 240, 1899.

[5]Merrill, G. P., Rocks, Rock Weathering, and Soils, p. 335, 1913.

Hornblende—This is a complex silicate frequently found in some impure clays. It weathers readily and colors the clay red, owing probably to its iron content.

Garnet—This is another complex silicate, which occurs as grains in some impure clays. Its effect is similar to that of hornblende.

Vivianite—$Fe_3P_2O_8$, $8H_2O$. A hydrous ferrous phosphate which may occur in some clays. It is not a common constituent of clays, but occurs in some Atlantic coast clays as small blue spots. Its presence in large quantities has not been determined.

Pyrolusite—MnO_2

Psilomelane—H_4MnO_5 These manganese oxides are usually secondary in origin and occur frequently in residual clays, but they are not, however, of very widespread distribution. In clays they rarely exceed one per cent. They exert a coloring effect similar to that of iron and are often the coloring agents on those clays used in mineral paint or pigments.

MINERALS IN BURNED CLAY

Very few attempts have been made to study the minerals in burned clay. Porcelain and some other types of high-grade products have been studied microscopically to some extent, but only about six investigators[1] seem to have carried on any experiments on clay alone. Somers apparently did the most exhaustive work so far attempted on American clays.

Somers' work shows that quartz usually stands out with much greater clearness in the burned than in the raw clay. He states that in a few cases a fluxing action appears to have taken place between the fine-grained material and the silica.

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[1]Vernadsky, W., Soc. franc, mineralogie Bull., Vol. 13, p. 256, 1890.
Glasenapp, M., Ueber Aenderungen der Mikostruktur der Tone durch Einwirkung hoher Hitzegrade: Tonindustrie Zeitung, Vol. 31, p. 1167, 1907.
Klein, A. A., The Constitution and Microstructure of Porcelain: American Ceramic Soc. Trans., Vol. 18, p. 377, 1916.
Mellor, J. W., Can the firing temperature of a body be determined from the microscopic appearance?: Eng. Ceramic Soc. Trans., Vol. 16, pt. 1, p. 71, 1917.
Somers, R. E., Microscopic Study of Clays, U. S. Geol. Survey, Bull. 709, p. 300, 1922.
Schurecht, H. G., The Microscopic Examination of the Mineral Constituents of some American Kaolins, Jour. of Am. Ceramic Society, Vol. 5, p. 3, 1922.

Hydromica, as the results of the same investigator show, either practically disappears at 1150° C. or loses the greater part of its interference color. Somers states that: "This change of the hydromica on heating suggests that it furnishes some of the flux for the clay, and other things being equal, there may be a connection between the degree of density at the temperature mentioned and the quantity of hydromica present."

Somers further states that: "If it is not fluxed, kaolinite appears to retain its shape and at least a part of its original interference color. Tourmaline and probably epidote disappear even at 1150° C., but rutile, zircon, and probably titanite seem to be unaffected even at 1300° C."

A white Florida clay fired at 1150° C. exhibited the formation of sillimanite. Somers believed it to have formed from large flakes of kaolinite or the low-grade hydromica. Other similar clays treated in the same manner did not develop sillimanite.

THE CHEMICAL ANALYSIS OF CLAYS

There are in common usage two methods of clay analysis. One of these is known as the ultimate analysis and the other as the rational analysis.

The ultimate analysis is the one most frequently used. It is the one which considers the various ingredients of a clay as oxides, yet their exact condition may be in much more complex forms. Calcium carbonate ($CaCO_3$) is thus considered as being broken up into carbon dioxide (CO_2) and lime (CaO), with the percentage of each given separately. The sum of these two percentages would, on the other hand, be equal to the amount of calcium carbonate in the clay. The common method of expressing the ultimate analysis of a clay is as follows:

Silica	(SiO_2)		
Alumina	(Al_2O_3)		
Ferric Oxide	(Fe_2O_3)		
Ferrous Oxide	(FeO)		
Lime	(CaO)		
Magnesia	(MgO)		Fluxing Impurities.
Potash	(K_2O)	Alkalies	
Soda	(Na_2O)		
Titanic acid	(TiO_2)		
Sulphur trioxide	(SO_3)		
Carbon dioxide	(CO_2)		
Water	(H_2O)		
Organic matter	....		

The ultimate analysis does not indicate what compounds are present in a clay, but at the same time some data can be derived from it. Ries[1] lists the following facts as obtainable from chemical analysis:

"1. The purity of the clay, showing the proportions of silica, alumina, combined water and fluxing impurities present. High-grade clays often show a percentage of silica, alumina, and chemically combined water approaching quite closely to kaolinite.

2. The approximate refractoriness of a clay; for other things being equal, a clay with high total fluxes, is commonly less refractory than one with low total fluxes. In this connection it is to be remembered that texture, irregularity of distribution of the constituents, and condition of kiln atmosphere are among conditions affecting the result.

3. The color to which the clay burns. This must be judged with caution. Assuming the constituents to be evenly distributed, then a clay with 1 per cent or less of ferric oxide is likely to burn white, but at high temperatures titanium if present produces discoloration. One with 2-3 per cent of ferric oxide is likely to burn buff; one with several per cent or more of ferric oxide will usually burn red if there is no excess of lime or alumina. It should be remembered that condition of the kiln atmosphere, texture of the clay, and sulphur in the fire gas may all affect the results.

4. The quantity of chemically combined water. Clays with a large amount sometimes show a high shrinkage, but there are many exceptions to this.

5. Excess of silica. A high percentage of silica (80-90 per cent) may indicate a sandy clay, and possibly one of low shrinkage, but does not necessarily point to a very lean one. High silica in a fire clay usually shows only moderate refractoriness provided it is evenly distributed.

6. Organic matter. This should be determined, as it causes trouble in burning if present to the extent of several per cent, requiring thorough oxidation in firing before the clay is allowed to pass to the vitrification stage.

7. Sulphur trioxide. Since this may be the cause of swelling in improperly burned wares, and also indicate the presence of soluble sulphates, it should always be determined.

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 62, 1908. New Jersey Final Report, Vol. VI, p. 50, 1904.

8. The presence of several per cent of lime and carbon dioxide shows the clay to be of calcareous character, and not only often of buff-burning character but with a narrow margin between vitrification and viscosity.

9. Titanium oxide should be determined, especially in fire clays, as a small quantity may reduce the fusion point of fire clay several cones.

It might be seen from the above that the ultimate analysis yields us much, and yet it leaves us practically in the dark as to the plasticity, air and fire shrinkage, density and hardness of burning, tensile strength, etc."

In modern clay investigation emphasis is placed on the physical tests and the ultimate analysis is rarely made because it is of little practical value except in rare cases.

The rational analysis attempts to resolve the clay into its constituent minerals, and in one sense of the word gives a more accurate conception of the true character of the material. The ordinary analysis divides the clay into: clay substance, quartz, and feldspar. The method as at present used is not by any means satisfactory, nor is it altogether safe to figure the mineral composition from the ultimate analysis.[1]

Methods of making both the ultimate and rational analysis are conveniently outlined in a number of publications dealing with clays and clay technology.[2]

CHEMICAL EFFECT OF VARIOUS CONSTITUENTS IN CLAYS

Silica—Silica may occur in a clay in the free state as quartz or it may occur in a combined state in the form of the silicate minerals. The common silicate minerals found in clays are kaolinite, hydromicas, feldspar, mica, hornblende, etc. The total silica is usually given in the ultimate analysis and includes both the free and the combined forms. Except in the case of kaolinite the silicate minerals occur in a more or less sandy condition and exert an influence upon the plasticity and shrinkage as does quartz. All of these affect the fire shrinkage and fusibility of the

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[1]Washington, H. S., The Calculation of the "Rational Analysis" of Clays, Jour. Am. Ceramic Society. Vol. I, p. 405, 1918.

[2]Washington, H. S., Manual of the Chemical Analysis of Rocks, 1919.

Hillebrand, W. F., The Analysis of Silicate and Carbonate Rocks, U. S. Geol. Survey Bull. 700, 1919.

Hillebrand, W. F., Some Principles and Methods of Rock Analysis, U. S. Geol. Survey Bull. 176, 1900.

clay. Indeed, sand is often added to some brick clays having a high shrinkage in order to reduce the shrinkage.

Contrary to the belief of some, the addition of quartz does not raise the fusion point of a clay. Quartz alone is very refractory, but in the presence of highly aluminous low-flux clays its refractoriness is reduced. A high percentage of silica for a very refractory clay is not desirable.

Alumina—Alumina is one of the common constituents of all clays and is derived not only from kaolinite but many of the other silicates as well. Alone it is highly refractory, but in the presence of fluxes its fusion point is lowered.

Iron Oxide—This includes both the ferric oxide, Fe_2O_3, and the ferrous oxide, FeO. The iron oxides in clay are derived from such iron minerals as limonite, hematite, pyrite, siderite, and also from such silicates as mica, hornblende, garnet, glauconite, etc.

Iron acts as a strong coloring agent in both the burned and unburned clay. Its range of color influence is from a very faint cream, through yellow and buff, to all shades of red, brown, and blue to black. The resulting color, however, is not solely determined by the quantity of iron oxide present but also by the texture and distribution in the clay, the form of the iron, whether ferric or ferrous, condition of the kiln atmosphere, whether oxidizing or reducing, and the neutralization effect of other constituents as lime.

The iron oxides likewise exert a strong fluxing action, thus lowering the fusion point of the clay. Ries[1] states that "this effect will be more pronounced if the iron is in a ferrous condition or if silica is present." The iron oxide probably enters into combination with silica, forming an easily fusible silicate.

Iron may therefore be either a desirable or an undesirable ingredient of clays. In the lower grades of ware its coloring and fluxing action is beneficial. The fluxing action reduces the temperature at which burning must be done. In other wares, such as white wares and refractory products, it is detrimental. It is obvious that in white-burning clays the iron content must be very low.

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 85, 1908.

Lime—Lime is found in one form or another in many clays, but all forms may be classed as carbonates, silicates, or sulphates. Calcite, or to a lesser extent dolomite, is the usual source of lime carbonate, gypsum is usually the source of the sulphate. Some silicates such as some of the feldspars and garnet may contain lime in combination, but the lime content of such silicates is usually quite low, and they therefore supply but little. When lime is present in the form of the carbonate, ($CaCO_3$), it may be detected by the application of an acid, as hydrochloric or nitric, which will react with the carbonate to produce an effervescence due to the escape of the carbon dioxide, (CO_2).

When in the form of the carbonate, lime is the most effective. If in a finely divided state it acts as a flux. When not in a finely divided state the carbonate changes to quicklime on burning with the loss of the carbon dioxide gas. The quicklime later takes up moisture from the atmosphere and slakes with accompanying swelling or crumbling.

Ries[1] states that: "If the temperature is raised higher than is required simply to drive off the carbon dioxide, and if some of the mineral particles soften, a chemical reaction begins between the lime, iron, and some of the silica and alumina of the clay, the result being the formation within the clay of a new silicate of very complex composition. The effects of this combination are several: In the first place the lime tends to destroy the red coloring of the iron and imparts instead a buff color to the burned clay. This bleaching action is most marked when the percentage of lime is three times that of iron. It should be remembered, however, that all buff-burning clays are not calcareous, and that a clay containing a low percentage of iron oxide may also give a buff body. Another effect of lime, if present in sufficient quantity, is to cause the clay to soften rapidly, thereby sometimes drawing the points of incipient fusion and viscosity close together and giving what is termed a short firing range.

This rapid softening of the calcareous clays is one of the main objections to their use, and on this account also it is not usually safe to attempt the manufacture of vitrified products from them, but the presence of several per cent of magnesia will counteract this. It has also been found possible to increase the interval between the points of incipient fusion and viscosity by the addition of quartz and feldspar."

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 87, 1908.

It is believed by many that a highly calcareous clay is entirely undesirable. This, however, is not always the case. Wisconsin clays[2], highly calcareous, produce a good building brick. When a vitrified ware is not attempted and the lime is in a finely divided and evenly distributed state, a good clay may contain as much as 20 to 25 per cent. It is interesting to note that the calcareous Wisconsin clays used in the manufacture of brick, are burned, with a few exceptions, at a much higher temperature than the non-calcareous ones[1].

The lime contained in the silicates have no noticeable detrimental or beneficial effects. While they may act as fluxes, they do not cause the ware to soften rapidly.

When lime is present in the form of the sulphate it will, when heated sufficiently high, be broken up into calcium oxide, (CaO), and sulphur trioxide, (SO_3). The sulphur trioxide may cause blisters or cracks in the ware as it escapes.

Magnesia—Magnesia may occur in the same form as lime, but the silicates in this case are the most important sources. In this form it acts in much the same manner as calcium silicate, but is not quite so active. While magnesia acts as a flux in firing it does not cause the clay to soften as rapidly as calcium and the points of incipient fusion and viscosity are more widely separated. Magnesium-bearing minerals which might occur in clays are biotite (black mica), hornblende, chlorite, dolomite, etc. The chlorite may be abundant in some partially decomposed residual clays and the dolomite in some sedimentary ones.

Alkalies—This term is used to include potash (K_2O), soda (Na_2O), and ammonia (NH_3). Ammonia is present in some raw clay, but as it is easily volatile it readily escapes when the ware is heated. Soda and potash, called the fixed alkalies, are present in almost every clay. The complex silicates, as mica, greensand, orthoclase, etc., are the principal sources of the alkalies in clays. Some alkali carbonate may be held in clay by adsorption. They are regarded as the most active fluxes present in clays. Except in the case of refractory clays, they are desirable constituents when in the form of silicates. By their fluxing action they bind the clay particles together in a dense hard body at a lower temperature than would otherwise be possible. It is for this reason that feldspar is used as a flux in many high-grade wares. There is practically no coloring effect exerted by the alkalies.

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[2]Clays of Wisconsin, Wisconsin Geological Survey, Bull. XV, p. 18, 1906.
[1]Clays of Wisconsin, Wis. Geol. Survey, Bull. 15, p. 36, 1906.

Titanium—Titanium is often regarded as an uncommon constituent of clays but in reality it is of frequent occurrence. Rutile and ilmenite are the most important sources of titanium dioxide in clays. Unfortunately tests for titanium are rarely made in a chemical analysis. It exerts a blue and yellow coloring effect and Ries[1] has shown that it lowers the refractoriness of clay. Veatch[2] states that titanium was shown in the analysis of some Georgia clays, but when those clays were examined microscopically no titanium minerals could be identified with certainty.

Water—This includes the mechanically combined water or moisture and the chemically combined water. The mechanically combined water is that held in the spaces between the clay particles by capillary action and can be driven off by heating the clay to the boiling point of water. The loss of this water causes the clay to shrink to a certain extent. This shrinkage, known as air shrinkage, ceases when the clay particles have all come in contact. The chemically combined water exists in combination with other elements and can only be driven off at a temperature ranging from 400° to 600° C.

Organic Matter—Organic matter, usually in the form of vegetable particles, occurs in many clays. It is a strong coloring agent in the unburned state and imparts to the clay a gray, blue, brown or black color. The same clays may, on burning, be red, buff, cream, or white, depending upon the other coloring agents. In such cases the carbonaceous matter has masked the other substances like iron in the raw state.

Carbon may interfere with the proper oxidation of iron and expulsion of sulphur when present. Clays with a high content of organic matter are of common occurrence in Florida.

It has been shown by the experiments of Orton and Griffin[3] that between 800° and 900° C. is the best temperature interval for burning off the carbon, as below this the oxidation of it does not proceed as rapidly, and above this there is danger of vitrification beginning and the oxidation being stopped. All the moisture should first be driven out of the clay, then the heat raised as rapidly as possible to a temperature between 800° and 900° C. and held there until the ware no longer shows a black core denoting ferrous iron.

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 104, 1908.

[2]Veatch, Otto, Clay Deposits of Georgia, Georgia Geol. Survey, Bull. 18, p. 48, 1909.

[3]Second Report of Committee on Technical Investigation, National Brick Makers' Association, Indianapolis, 1905.

Sulphur—The determination of sulphur is rarely made in the analysis of a clay unless it is being considered for the manufacture of Portland cement. It sometimes occurs, however, in clays and when present is usually in the form of sulphate or sulphide. Orton and Staley[1] concluded, from a series of experiments carried on by them, that sulphur retained in the clay during the period of burning, regardless of its form or cause of retention, is not likely to cause any physical disturbance until a fairly complete degree of vitrification is reached, but when a dense vitrified state is reached it soon becomes less dense, on account of the formation of multitudes of minute vesicles in the viscous body, and finally the body becomes spongy and worthless. They further conclude: "That in clays of low sulphur content, and of favorable structure for oxidation, the amount of sulphur left in the clay at vitrification is very small. Hence the period of good structure is long, the vesicular structure develops slowly, and the clay is said to stand overfiring well.

"In some clays of high sulphur content or of dense structure unfavorable for oxidation, or of high content of iron and carbon, the escape of sulphur is prevented, the clay has a narrow period of usefulness, or none at all, and the vesicular structure becomes enormously exaggerated."

Soluble Salts—Soluble salts is a term applied to those compounds readily soluble in water which are found in practically all clays to a greater or less degree. Upon being dried the moisture in the clay carries these compounds to the surface where it leaves them, upon evaporation, as an efflorescence. This effloresence or white coating may also occur in the burned product after exposure to moisture.

The term "effloresence" and "scum" have hitherto been used interchangeably to describe the accumulation of the salts (coating) upon the surface where they have been brought in solution and deposited upon the evaporation of the water. Parmelee[2] suggests that the usage of the term effloresence be limited only to include those surface deposits of salts that accumulate on raw clays in their original beds or in storage bins; all those surface deposits which occur in the drying of the ware,

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[1]Third Report of Committee on Technical Investigation, National Brick Makers' Association, Indianapolis, 1908.

[2]Parmelee, C. W., Soluble Salts and Clay Wares, an address before the Indiana-Illinois Division of the American Face Brick Association. Chicago, April 11, 1922.

except those cases where the ware is dried by the waste heat from burning kilns; all coatings of soluble salts in masonry work in walks, piers, etc., which have originated through the solvent action of water upon materials in the clay wares or has been contributed by the mortar used; and those coatings of soluble salts brought to the surface during the early stage of burning (water-smoking period). He also suggests that the term scum be limited to designate all those surface coatings of soluble salts which have originated through deposits upon the surface of volatile substances. This distinction is adhered to in the following discussion of soluble salts:

Soluble salts brought out in the drying of the ware are termed "dryer white," those appearing in the process of burning are "kiln white," and those which come to the surface of the finished product after being exposed to moisture are "wall white".

While soluble salts are present in all clays they may occur in various forms and may result from several causes. Not all of these, however, are harmful. It also sometimes happens that other conditions intervene in behalf of the manufacturer to reduce the harmful effect of the more objectionable ones.

These soluble salts may occur as the hydrated silicic acid, as aluminum salts, as the sulphates of iron, calcium, magnesium, sodium, potassium, etc., also as sodium chloride or common salt. Some of the compounds of vanadium at times occur as soluble salts. The calcium and magnesium sulphates are the most troublesome and incidentally are the ones most frequently found.

The soluble salts may be present in the clay in its raw state; they may result from the decomposition of certain mineral impurities in the clay as pyrite, upon exposure to moisture and air; they may be introduced by gases coming from fuel used in drying or burning; or they may be brought into the clay by the water used in tempering. In any case where soluble salts occur the water used should be considered. Parmelee[1] has pointed out that clay particles are of very minute size and when these are subjected to prolonged contact with water they are more or less taken into solution. Thus, the same writer adds, the determination of the amount of the soluble salts in clays is seriously com-

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[1]Loc. cit.

plicated by the progressive solubility of clay in contact with water, so that the duration of the contact and the temperature are extremely important factors.

If pyrite is present in a clay it oxidizes when exposed to air and moisture to form the soluble iron sulphate. Its presence may often be detected by a yellow or brownish-yellow efflorescence on the raw clay. It is oxidized during burning to red or brown. The iron sulphate decomposes with the formation of sulphuric acid which then attacks the calcium, magnesium, or iron compounds to form the sulphates of these elements. In some cases organic acids present in many clays may attack calcium carbonate (often in the form of limestone) to form some of the soluble salts.

The maximum amount of soluble salts which may be present in a clay without detrimental results is not known. It is placed by some investigators at as low as one-tenth of one per cent. Dr. Mäckler[1] says: "The amount of scum (efflorescence) formed on finished goods bears no definite relation to the proportion of soluble salts contained, but there is quite a definite relation between the amount of the magnesium and sodium sulphates and that of scum (effloresence)." On this point Staley[2] writes "that he added calcium sulphate to a fine-grained, red-burning shale in amounts increasing to 3 per cent of the dry clay and was unable to produce effloresence even with slow drying. When he added 1 per cent of magnesium sulphate it appeared in large quantities and a 1 per cent mixture of equal parts of the sulphates of calcium and magnesium give an even greater amount of effloresence." He explains this by pointing out that magnesium sulphate is very soluble in water while calcium sulphate has only a slight solubility. He also states that calcium sulphate hastened the rate of drying which would act toward a decrease in effloresence.

There are several methods of preventing the troublesome effect of soluble salts. The numerous remedies which have been suggested and used depend upon the character, origin, and occurrence of the salts in the clay in question. In some cases use of the clay in the unweathered condition is desirable. In other cases prolonged and thorough weathering will permit the objectionable compounds to be leached out. Rapid

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[1]Quoted in Clayworkers' Handbook, p. 213, 1906.

[2]Staley, Homer F., Use of Barium Fluoride for the Prevention of Dryer Scum on Bricks. Trans. Am. Ceramic Soc., Vol. XVII, p. 200, 1915.

firing may prevent the concentration of the salts on the surface of the brick or using a reducing flame in the kiln may counteract the ill effects at times. Coating the ware with some organic substance such as rubber, tar, or flour is often satisfactory. Washing the clay in much the same manner as is followed in the sedimentary kaolin mines in Lake and Putnam Counties will usually accomplish the desired result, but this method is somewhat expensive except for high-grade wares. Probably one of the most satisfactory methods of prevention is to convert the soluble salts into insoluble compounds. This can be accomplished by reactions with barium compounds. For example, if a clay containing calcium sulphate is treated with barium chloride the insoluble barium sulphate and calcium chloride results. The calcium chloride is decomposed in burning without harmful results. There are several ways in which this general method can be applied.

CHAPTER IV

PHYSICAL PROPERTIES OF CLAYS

Clays possess certain characteristics which are of a physical nature and which are variable in different clays. The value of a clay for the manufacture of clay products depends upon these physical properties. Herein lies the necessity for determining the possibilities and limitations of a clay by a series of physical tests. These also determine the kind of product for which the clay is best suited. The more important physical properties will be briefly treated.

PLASTICITY

Plasticity is one of the most important properties of a clay, for without it the manufacture of ordinary clay products would be greatly limited. Plasticity has been defined as the property possessed by a clay of forming a plastic mass when mixed with water; this definition is satisfactory only when applied to clay because plasticity is not a property of clay alone. Ries[1] defines plasticity as "the property which many bodies possess of changing form under pressure, without rupturing, which form they retain when the pressure ceases, it being understood the amount of pressure required, and the degree of deformation possible, will vary with the material."

The degree of plasticity varies greatly in different clays. Clays showing a high degree of plasticity are said to be "fat," while those which are only slightly plastic are "lean" or "short." No satisfactory method for measuring plasticity has as yet been devised. The description of the plasticity of a clay is largely a matter of individual judgment and varies with the personal equation.

The amount of water required to develop the maximum plasticity in any clay varies with the material. It ranges from eight or ten per cent in some to over forty per cent in others.

The cause of plasticity is not thoroughly understood, and while many theories have been advanced to explain it no one of them seem to fit every case.

The structure of the clay particles has been used in several attempts to explain plasticity. The *fineness of grain* theory is that plasticity is due

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[1]**Ries, H., Clays, Their Occurrence, Properties and Uses, p. 119, 1908.**

solely to the fineness of the clay particles. Other substances, however, when ground equally fine do not have the plasticity that clay has. The *plate structure* theory is that clay is made up of very fine plates which afford plasticity when mixed with water. All clays, however, do not show this platy structure. The *interlocking particles* theory is that the tiny particles interlock and thus afford plasticity.

An attempt has also been made to explain by virtue of the presence of *hydrous aluminum silicates,* that is to say the plasticity is due to the hydrous aluminum silicate condition, and that the application of heat drives off the chemically combined water thus destroying plasticity. The degree of plasticity, however, does not stand in any relation to the chemical composition.

Efforts have likewise been made to explain plasticity by molecular attraction and by the presence of colloidal matter. This supposes that these colloids take up water and thus become jelly-like and plastic.

It does not seem likely, in the examination of a series of clays, that any of the theories as yet suggested is the sole cause of plasticity. It is more probable that plasticity is due to a combination of them.

Some clays are too highly plastic to be handled with maximum facility in the common types of machinery. In such cases a non-plastic substance, as sand, is added to the clay to reduce the plasticity.

COLOR

The color of a clay is quite variable, ranging from white through gray, yellow, brown, red to black. Vegetable matter and the nature of the iron compounds present usually determines the color of a clay, though manganese is sometimes an important factor.

The color of the raw clay is not always indicative of the color of the burned product. If the raw clay is red because of the presence of iron compounds, the burned product is likely also to be red. The presence, however, of sufficient calcium carbonate would tend to neutralize the coloring effect of the iron and cause a buff or cream color instead. The presence of carbonaceous matter will have little influence, if any, on the color of the burned product. It moreover masks the true color of the raw clay. The colors in burned clays are not as variable as in the raw ones. White, cream, buff, yellow, and red are the common colors in burned products.

TEXTURE

The size of grains composing clay varies from small pebbles to extremely minute particles. In fact, these finer particles are at times so small as to remain in suspension in water an indefinite period. The size of grains, or texture, has an important influence in clays on their plasticity, shrinkage, porosity, fusibility and strength.

Several methods of determining the texture of clays are commonly followed, and these are very similar to the methods used in the mechanical analysis of soils.[1]

SLAKING

Some clays when immersed in water will crumble to a powder in a few minutes, while others will at first break up into small masses which subsequently crumble. This process is known as slaking, and the test is usually made by mixing the clay with equal parts of ground potter's flint. The time necessary for a clay to slake varies from a few minutes in soft porous ones to several days or even weeks in others.

A clay which slakes easily can be tempered more readily, and in case of a clay which must be washed, one which slakes readily is more rapidly disintegrated in the process.

SHRINKAGE

All clays exhibit a reduction in size in drying and burning which is termed shrinkage. The first is the air-shrinkage and the latter is the fire-shrinkage. Both fire- and air-shrinkage are commonly measured in two ways, by volume or by linear determinations. The volume (or cubic) shrinkage is obtained by determining the volume of the test piece when first molded and again after drying or burning. The linear shrinkage is measured directly on the ware and expressed in percentage terms of the original length.

In clay containing no water the clay particles are all in contact with each other. There are spaces, however, left between the particles. When the clay is brought into contact with water, these interstitial spaces are filled without the clay changing form. The water necessary to fill these interstitial spaces is termed the pore water. If additional water is

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[1]U. S. Dept. of Agriculture, Bur. of Soils. Bull. 4, p. 9, 1896.
U. S. Dept. of Agriculture, Bur. of Soils. Bull. 64, 1900.

added it causes an increase in volume or swelling of the clay. This additional water absorbed by the clay is in the form of a film surrounding each particle of clay.

After a clay is mixed with water and molded, its water begins to evaporate. As evaporation progresses the particles composing the clay come again in contact, resulting in a shrinkage of the mass. This will continue until all the water forming a film around the clay grains has escaped and the clay particles are in contact with each other. This is the point of maximum air-shrinkage if the water lost is the shrinkage water. The only moisture remaining in the clay is the pore water which can only be driven off by heating the ware to 100° C. for a few hours.

The air-shrinkage in clays ranges from less than one per cent to more than fifteen per cent. Six or seven per cent is about the average. Sand is often added to clays to reduce an excessive shrinkage.

All clays shrink to some extent during certain stages of the burning process. The fire-shrinkage varies within wide limits in different clays and ranges from one or two per cent in some to more than forty per cent in others. At certain temperatures some clays may expand to some extent. Fire-shrinkage results from the driving off of any organic matter present, decomposition of some of the chemical compounds and the volatilization of certain substances as water in the hydrous minerals and carbon dioxide in the carbonate minerals present, etc.

Fire-shrinkage probably begins at the point where chemically combined water begins to pass off and continues, but not uniformly, until the point of vitrification is reached, which is the point of maximum density.

After the expulsion of the volatile elements the clay is left in a porous condition until the fire-shrinkage recommences. Ries[1], in experimenting with New Jersey clays, found: "That most of the volatile substances, such as chemically combined water contained in the hydrous aluminum silicates, mica, or limonite, and organic matter, pass off before 500° C. and that an additional appreciable amount is expelled between 500° C. and 600° C. Between 600° C. and 1100° C. there was a small but steady loss. Although the loss in weight between 500° C. and 900° C. is considerable, there is little or no shrinkage, so that after the volatile

[1]Ries, H., The Clays and Clay Industry of New Jersey, New Jersey Geological Survey Report, Vol. VI, p. 94, 1904.

elements have been driven off, the clay must be very porous, and remains so until the fire-shrinkage begins again. In these tests, with one exception, no shrinkage occurred between 600°C. and 900°C., but between 900° C. and 1000° C. there was a decrease in size and a still greater reduction between 1000° C. and 1100° C. It can be seen from this that up to 600° C. a clay should be heated slowly, but from that point up to 1000° C. the temperature can be raised quite rapidly unless much carbonaceous matter is present. Further heating should be done slowly as the shrinkage recommences at the last-mentioned temperature."

In some clays having an excessive fire-shrinkage and where severe losses occur from warping and cracking a substance having no fire-shrinkage, a sand or grog (ground bricks, etc.), is often added. Sand, however, may act as a flux at high temperatures.

FUSIBILITY

All clays fuse or melt at some temperature and the temperature at which this action takes place is quite variable in different clays. In fact, clays are often classified on the basis of their refractoriness. Every mineral has a definite temperature at which it will fuse and this point is usually different for different minerals, but in the case of a mixture of minerals the point of fusion may be different from that of any mineral in the mixture. Thus the fusion point of clay, which is a mixture of several minerals, may fuse at a temperature different from the melting point of any of its mineral components. In such cases the minerals act as a flux on each other. Clays soften slowly due to different mineral grains entering into fusion at different temperatures.

Ries[1] says that in the case of clays "the temperature of fusion depends on (1) the amount of fluxes; (2) the size of grain of the refractory and non-refractory particles; (3) the homogeneity of the mass; (4) the condition of the fire, whether oxidizing or reducing; and (5) the form of chemical combination of the elements contained in the clay."

Three stages are commonly recognized in the heating of a clay to its fusion point. The first is *incipient vitrification,* in which there has been sufficient softening to cause the grains to stick together. In this stage the individual grains can no longer be recognized. All the pore spaces, however, have not closed. The second stage is known as *complete vitrifiica-*

[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 166, 1908.

tion and is accompanied by a sufficient softening of the mass to close all the pore spaces and render the mass impervious. The point of maximum shrinkage is also attained in this condition. The stage of *viscous vitrification* is characterized by further softening or swelling of the clay until it flows or becomes viscous.

It is often quite difficult to recognize just when these three periods have been reached as the change from one to the other is frequently very gradual. In other cases the transition is quite sudden. The temperature necessary to change a clay from one of these conditions to the other is dependent upon the composition of the clay and is therefore variable. The difference in temperature between the points of incipient vitrification and viscosity may be less than 30° C. in calcareous ones to more than 275° C. in refractory clays.

In the manufacture of clay products it is not possible to regulate the temperature of the kiln within narrow limits. It therefore becomes necessary to use a clay in which the points of incipient vitrification and viscosity are somewhat separated, particularly if a vitrified ware is to be produced. If a clay with a short firing range, as the range in temperature between incipient vitrification and viscosity is termed, is used there is danger of either not reaching the point of complete vitrification or going too far beyond this point and melting the contents of the kiln.

Orton[1] has very completely discussed the nature of the vitrification process and points out that "any clay which is greatly overloaded with quartz sand, or with large proportions of carbonate of lime, or almost any other common mineral . . . vitrifies with great difficulty, and with a very imperfect degree of vitrification at best. It is not only not at all uncommon in practical work to find clays which will work well for ordinary porous clay products such as building bricks, and still not vitrify to anything approximating industrial requirements, but it may fairly be said that there are more clays used industrially which fall outside of the commercially vitrifiable class than fall in it. . . . The preliminary stages of burning are vitally important in preparing the minerals to combine and fuse into a solid solution. By the time the temperature reaches 900° C. the compounds, (silicates, both hydrous and anhydrous, oxides, hydroxides, carbonates, sulphides, free carbon, hydrocar-

[1]Orton, Edward Jr., The Legal Definition of Vitrification, Trans. American Ceramic Society, Vol. XVI, p. 497, 1914.

bons, etc.), derived from the original minerals should have been converted into stable forms, . . . and nothing should be left except what may enter into a silicate solution. The normal beginning of the reaction in the vitrification process is from little spots or foci scattered throughout the body, . . . each focus being represented by some easily fusible mineral grain, or the juxtaposition of two or more mineral grains which combine to form a eutectic or the most fusible ratio in which these minerals can combine. . . . The spread of the glassy cement from focus to focus in a clay of good vitrifying character is slow and steady, and the proportion of grains which will not readily dissolve is such that they readily form a sort of skeleton or frame work, holding the mass in its shape, while the glassy cement slowly decomposes them and fills up the voids, causing the well-known phenomenon called shrinkage. . . . Practically all silicates when passing from the solid state to a state of complete fusion, give off some gaseous matter. It may be the gas which they have held in solution and which is then occluded, or it may be from remnants of volatile matter not hitherto expelled, or it may be due to the swelling of gases caught in the interstitial voids of the mass during the shrinkage and unable to escape. Probably all three causes are responsible in most cases. . . This swelling agency is at work as soon as the formation of glassy cement begins. . . . If the process of fusion be carried along steadily until a fluid bath is obtained, the liquid will pass into a frothy stage in which the gas bubbles work their way to the top and escape, . . . but with continued heat and liquidity the bubbles finally cease to form. . . . It can thus be seen that the clay product, in reaching its point of greatest density, does not reach the point where the gases are fully expelled but only the highest point attainable *without causing their evolvement to seriously begin.* This maximum density is found at a point where the reduction in volume due to shrinkage is equalized by the expansion due to gases evolved. One force balances the other and for a time the volume of the clay remains constant. This time may be long or short. In some clays of most excellent vitrifying habit, a heat treatment represented by five or six cones may occur with scarcely any change in size. In others the volume diminishes rapidly and at the minimum point begins at once to swell again, with no appreciable interval. Such clays cannot be burned profitably into hard products. There is no margin in which the burner can regulate his kiln, and a part of every kiln would

surely be overfired and bloated, part would be at its best density, and part would be underfired and not up to its best density. Such clays are said to have a short firing range."

The fusibility of clays may be measured in several ways. This is most frequently done by use of Seger cones, the thermoelectric pyrometer, or an optical pyrometer.

The Seger cones consist of small slender pyramids of known composition (clay and fluxes) which fuse at definite temperatures. They are arranged to represent a series of fusion points, each cone melting at a few degrees higher than the next one below it in the series. In actual practice these cones are placed in a protected place in the kiln where they will not be in the direct flame and yet will receive the average heat from the fuel. They are placed in such a position that they can be watched through a peep-hole. If it is desired to reach a certain temperature in a kiln, a cone representing the temperature and two or three lower cones are placed in the kiln in such a way that they may all be observed. The lower cones melt at lower temperatures and therefore indicate that the desired temperature is being approached. For example, cones 1, 3, and 5 may be used. When Nos. 1 and 3 are bent over in burning and No. 5 is still standing erect the temperature is between cones 3 and 5.

The cone cannot be regarded as an exact measure of the degree of temperature. It in reality measures pyrochemical effects instead and represents the conditions of time and heat which will accomplish certain results in fusion and vitrification. The cones usually melt quite close to their theoretic fusion point, if heated slowly.

These cones have had a wide application in the ceramic industries and are almost invariably used by the manufacturers of high-grade products. They are used in several of the brick and pottery plants in Florida.

Throughout the United States the following cone numbers are commonly used for the classes of ware indicated:[1]

Common brick	012-01
Hard burned, common brick	1-2
Buff front brick	5-9
Hollow block tile and fireproofing	03-1
Terra-Cotta	02-7

[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 187, 1908.

Conduits	7-8
White earthenware	8-9
Fire bricks	5-14
Porcelain	11-13
Red earthenware	010-05
Stoneware	5-8
Electric porcelain	10-12

For the composition and fusion temperatures of the Seger cone series see Appendix B. A comparison of various temperatures used in the different kinds of products is shown in Fig. 1.

The thermoelectric pyrometer is to a great extent replacing the use of the Seger cones in measuring temperatures. The greatest difficulty with its use is the cost of the apparatus. The type most widely used consists of two wires, one of platinum and the other of an alloy of platinum and rhodium or platinum and iridium, which are fused together at one end while the free ends are connected with a galvanometer. One of the wires is encased in a small quartz tube to insulate it from the other. The two wires are then placed in a larger quartz or porcelain tube which is inserted into the kiln. The heating of the thermopile in the furnace generates an electric current which is conducted to the galvanometer which measures the intensity of the current. The degrees of temperature are measured by the amount of deflection of the needle of the galvanometer. The galvanometer may be installed in the office some distance from the kiln and the temperature may thus be observed at will. Some types of this instrument have an automatic recording device.

The optical pyrometer is used to some extent in measuring temperatures. There are several forms on the market. The principle of some of these is to compare the intensity of light in a furnace with that from some other source. In others the light emitted from the furnace is refracted by means of prisms and a comparison is then made with some standard.

POROSITY

The porosity of a clay is the volume of pore space existing between the clay particles and thus depends upon the size and shape of the particles making up the mass. Spherical grains would give a maximum porosity, but clays of this type are probably unknown. In clays the grains vary in size and are irregular in shape, which greatly reduces the porosity. It has been shown, however, that increasing fineness means increasing pore space. Porosity determines the amount of water a clay will

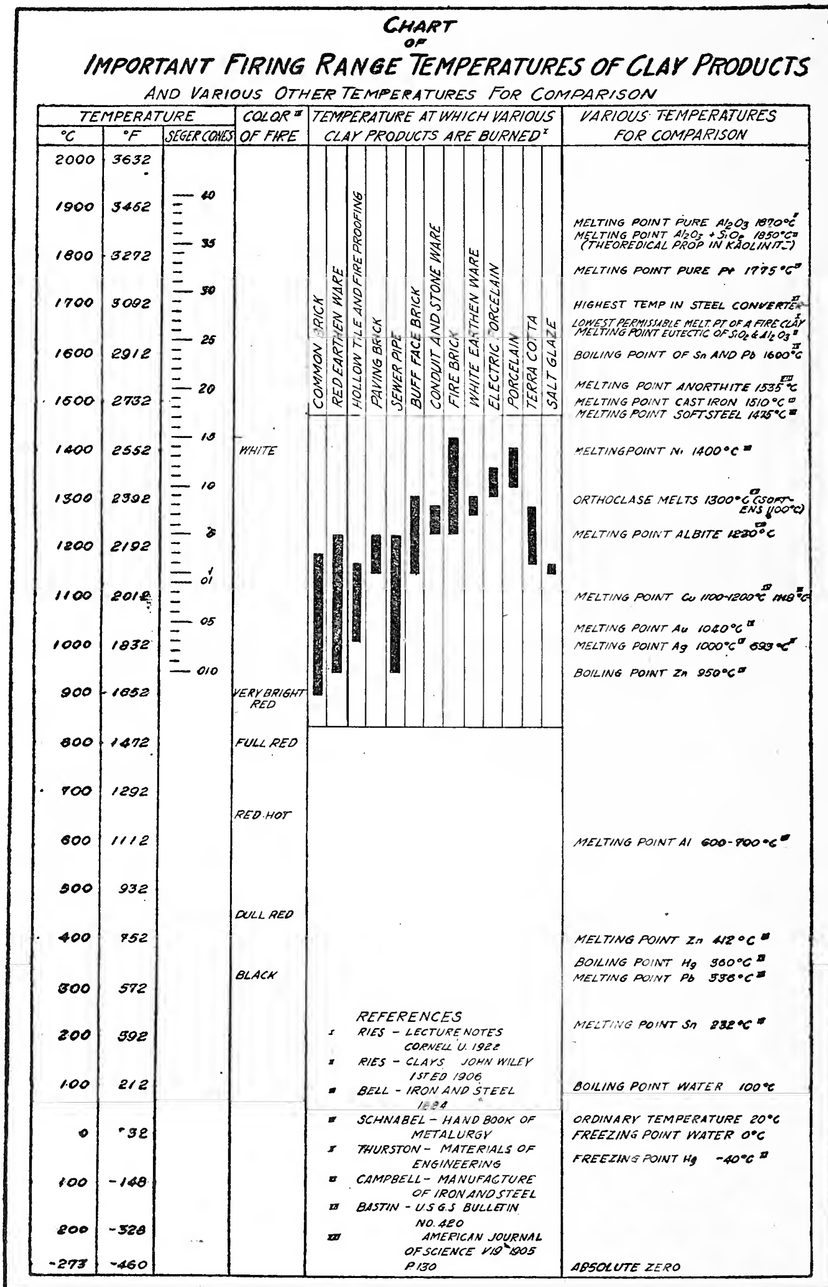
CHART OF
IMPORTANT FIRING RANGE TEMPERATURES OF CLAY PRODUCTS
AND VARIOUS OTHER TEMPERATURES FOR COMPARISON
TEMPERATURE
°C
°F
SEGER CONES
COLOR OF FIRE
TEMPERATURE AT WHICH VARIOUS CLAY PRODUCTS ARE BURNED
VARIOUS TEMPERATURES FOR COMPARISON
2000 3632
1900 3452
1800 3272
1700 3092
1600 2912
1500 2732
1400 2552
1300 2392
1200 2192
1100 2012
1000 1832
900 1652
800 1472
700 1292
600 1112
500 932
400 752
300 572
200 392
100 212
0 32
100 -148
200 -328
-273 -460
40
35
30
25
20
15
10
5
1
01
05
010
WHITE
VERY BRIGHT RED
FULL RED
RED HOT
DULL RED
BLACK
COMMON BRICK
RED EARTHEN WARE
HOLLOW TILE AND FIRE PROOFING
PAVING BRICK
SEWER PIPE
BUFF FACE BRICK
CONDUIT AND STONE WARE
FIRE BRICK
WHITE EARTHEN WARE
ELECTRIC PORCELAIN
PORCELAIN
TERRA COTTA
SALT GLAZE
MELTING POINT PURE Al_2O_3 1870°C
MELTING POINT Al_2O_3 + SiO_2 1850°C
(THEOREDICAL PROP IN KAOLINITE)
MELTING POINT PURE Pt 1775°C
HIGHEST TEMP IN STEEL CONVERTER
LOWEST PERMISSABLE MELT. PT OF A FIRE CLAY
MELTING POINT EUTECTIC OF SiO_2 & Al_2O_3
BOILING POINT OF Sn AND Pb 1600°C
MELTING POINT ANORTHITE 1535°C
MELTING POINT CAST IRON 1510°C
MELTING POINT SOFT STEEL 1475°C
MELTING POINT Ni 1400°C
ORTHOCLASE MELTS 1300°C (SOFTENS 1100°C)
MELTING POINT ALBITE 1230°C
MELTING POINT Cu 1100-1200°C 1118°C
MELTING POINT Au 1040°C
MELTING POINT Ag 1000°C 693°C
BOILING POINT Zn 950°C
MELTING POINT Al 600-700°C
MELTING POINT Zn 412°C
BOILING POINT Hg 360°C
MELTING POINT Pb 336°C
MELTING POINT Sn 232°C
BOILING POINT WATER 100°C
ORDINARY TEMPERATURE 20°C
FREEZING POINT WATER 0°C
FREEZING POINT Hg -40°C
ABSOLUTE ZERO
REFERENCES
I RIES - LECTURE NOTES CORNELL U. 1922
II RIES - CLAYS JOHN WILEY 1ST ED 1906
III BELL - IRON AND STEEL 1884
IV SCHNABEL - HAND BOOK OF METALURGY
V THURSTON - MATERIALS OF ENGINEERING
VI CAMPBELL - MANUFACTURE OF IRON AND STEEL
VII BASTIN - U.S.G.S BULLETIN NO. 420
VIII AMERICAN JOURNAL OF SCIENCE V.19 1905 P.130

FIG. 1.

absorb and in this way influences the amount of air-shrinkage. Porosity also influences the rate at which the ware can be dried. The larger the pore space the more rapidly the water can escape. Also in the burning process a clay remains porous until the point of vitrification is reached. A low porosity in burned products is usually desired.

TRANSVERSE STRENGTH

The transverse strength is the resistance which an air-dried clay offers to rupture or breakage. It is usually expressed as modulus of rupture in pounds per square inch. It was formerly the custom to determine the tensile strength of a clay in much the same way that cements are tested. It has been shown, however, that the tensile strength stands in direct relation to the transverse strength.[1] The transverse strength test is in reality a closer approximation of the conditions to which the ware is subjected before burning, and for that reason is the test commonly applied in modern clay investigation. The transverse strength is an index of the ability of the clay to withstand the shocks and strains of handling incident to its molding, drying, and preparation for firing. A clay of high strength will suffer less loss from breakage in the manufacturing process than a clay of low strength.

BONDING STRENGTH

The bonding power of a clay is its ability to withstand the addition of non-plastic material. A clay which will allow the addition of a large amount of sand, for example, without seriously affecting its strength is said to have a high bonding power. The bonding power of a clay is of practical importance because in the manufacture of high-grade wares as electric porcelain, chinaware, etc., non-plastic ground flint and feldspar are often added.

[1]Ries & Allen, Trans. Am. Ceramic Soc., Vol. XII, p. 141, 1910.
Bleininger and Loomis, Trans. Am. Ceramic Soc., Vol. XIX, p. 601, 1917.

CHAPTER V

TESTS MADE UPON CLAYS

The methods of testing clays are now fairly well standardized and are somewhat uniformly followed with the result that clay technologists and investigators have a reliable basis upon which to compare the properties of various clays.

The measurement of the *plasticity* of a clay still remains a matter of personal opinion, for no satisfactory means of measuring it has as yet been devised. The terms employed to describe the plasticity of a clay are only relative and will of course vary to some extent with the individual. Plasticity is usually described as "good", "excellent", "poor", "low", etc. A clay having good or excellent plasticity is said to be "fat", and one having low or poor plasticity is described as being "lean."

The *water of plasticity* is a more definite factor and can thus be accurately measured. The water of plasticity is the amount of water necessary to give a clay its maximum plasticity. It is expressed in terms of percentage based upon the dry weight of the clay and is determined by weighing a test piece at maximum plasticity and again weighing it after all the moisture has been driven out by first drying at room temperature and finally at 110° C. until it has a constant weight. The water of plasticity test indicates the amount of water necessary to bring a clay to its point of maximum plasticity in which state it can be best worked.

The *shrinkage water* is that portion of the water of plasticity which escapes up to the point where air-shrinkage ceases, or in other words, it is the water lost in air-drying. The clay without the shrinkage water is at the point of maximum air-shrinkage in which condition the clay particles are in contact.

The *pore water* is that portion of the water of plasticity which remains in the inter-particle spaces after the point of maximum air-shrinkage has been reached. It can be driven off only by heating the test pieces to 110° C. The pore water plus the shrinkage water is the water of plasticity.

The *slaking* of clays is the property possessed by them when dry, of crumbling into a flaky or pulverulent mass when immersed in water. In order to determine this property it is necessary to first dry the test pieces at room temperature. Then all the remaining moisture is driven off by heating them for two hours or longer at 110° C. They are then

placed on a screen having four meshes to the inch and carefully immersed in water. The time required for the clay to disintegrate and fall through the screen is noted.

The plasticity of certain clays is increased by weathering which thus facilitates tempering. The slaking test indicates the weathering quality of a raw clay and may be employed to ascertain whether or not weathering would facilitate handling. Also a clay which slakes readily is more easily washed than one requiring a long time for slaking.

In the case of high-grade clays a mixture of 50 per cent clay and 50 per cent potter's flint is made into test pieces and slaked. This is one indication of the bonding strength of the clay.

In the determination of *volume air-shrinkage* the volume of the test piece is determined in cubic centimeters. Then it is allowed to dry at room temperature followed by a period of drying at 110° C. until constant in weight. The volume in cubic centimeters is again determined and the loss in volume is calculated in percentage terms of the dry volume.

The *linear air shrinkage* is computed by determining the reduction during drying in the length of a line of known length marked upon the test piece when freshly molded. This shrinkage is expressed in percentage terms of the original plastic length.

The *volume fire shrinkage* is determined after firing at the respective temperatures. The reduction in volume after the completion of the air shrinkage is determined in cubic centimeters and calculated in percentage terms of the original dry volume.

The *linear fire shrinkage* is determined after firing at the various temperatures in the same manner as the linear air shrinkage. It is expressed in percentage terms based upon the wet length of the mark.

Both the linear air and fire shrinkage may also be calculated from the volume shrinkage formula. The volume and linear shrinkage are simply two different methods of expressing the same property of a clay. The shrinkage of a clay both in drying and in firing is obviously an important factor.

The *absorption* test is made to determine the amount of water a clay will absorb. The weight of the test pieces after each firing is determined, after which they are immersed in water at room temperature for twenty-four hours and weighed again. The absorption is the amount

of water absorbed expressed in percentage terms of the dry weight of the fired test piece and is obtained by the following formula:

$$\frac{\text{Absorbed weight—dry weight}}{\text{dry weight}} \times 100 = \% \text{ absorption.}$$

A knowledge of the amount of water possible for a clay to absorb is very desirable as this property may seriously affect its usefulness. A small percentage of absorption indicates that the ware will absorb a correspondingly small amount of moisture. This in turn indicates a better resistance to frost action, less likelihood of the appearance of soluble salts and also indicates the general hardness of the ware as well as the general progress of vitrification.

The *porosity* of a clay is an expression of the pore space it contains. The porosity is determined after each firing by boiling the test piece in water for one hour after it it has absorbed as much water as it will. This causes the piece to become saturated. Its weight suspended in water is also obtained. The porosity is expressed in percentage terms of the original weight of the test piece and obtained by the following formula:

$$\frac{\text{Saturated weight—dry weight}}{\text{Saturated weight—suspended weight}} \times 100 = \% \text{ porosity.}$$

By use of the porosity determination the progress of vitrification is known. The point of minimum porosity, or maximum density, is the point of complete vitrification. If plotted on cross-section paper where percentage of porosity and temperature are the factors, the resulting curve drops more or less uniformly until it approaches the temperature of vitrification, rising again as the temperature of viscosity is reached. When the porosity increases the clay is said to be overfired. The porosity of a clay product is regarded as an important factor in its durability and non-conductivity to heat.

Porosity and absorption stand in direct relation to each other. The curves, when plotted, are essentially parallel. The determination of absorption is essential in structural materials and porosity in fireproofing ware.

The *transverse strength* or *tensile strength* indicates the ability of a clay to withstand the shocks and strains of handling. The transverse

strength and tensile strength stand in direct relation to each other. The tensile strength is determined by molding the clay into briquettes similar to those employed in testing cement. These, after being properly dried, are pulled apart in a tensile strength machine. The cross section of the tensile strength in pounds per square inch is computed. The tensile strength test is now superceded by the transverse strength test.

In determining the transverse strength, bars of clay six inches long and one inch in cross-section are made. They are then thoroughly dried first at room temperature and finally at 110° C. After the width and thickness of the bars are measured they are placed on supports six inches apart and pressure is applied to the upper surface midway between the supports. The modulus of rupture is then computed in pounds per square inch by the following formula:

$$\text{Modulus of Rupture} \ldots\ldots\ldots\ldots \frac{3\,w\,l}{2\,b\,h^2}$$

Where w is the breaking load,
l the distance between supports,
b the breadth of the bars, and
h the height of the bars.

The *bonding test* is made in order to determine the bonding power of a clay. This is made by mixing equal parts of standard sand and clay and the mixture is molded into bars and broken as in the transverse strength test. The modulus of rupture is then calculated. The bonding power of a clay is its ability to carry quantities of non-plastic material. The modulus of rupture of the sand-clay mixture may be either higher or lower than that of the clay alone.

The *color* of a fired clay is always of importance and hence is noted. This is particularly necessary since the color of the raw clay is no indication of its fired color.

CHAPTER VI

KINDS OF CLAYS AND THEIR USES

This discussion of the kinds and uses of clays is based upon the commercial classification and is in no way related to their geological occurrence or origin. The use of any one clay, moreover, is not always restricted to the general type of ware mentioned here, but may be employed for other purposes as well. For example, a stoneware clay may be used for roofing tile or terra-cotta, but its chief value lies in the fact that it is adapted for the manufacture of stoneware.

KINDS OF CLAY

Kaolin—This term was formerly used to include only a refractory white-burning residual clay composed mostly of silica, alumina, and chemically combined water with a low percentage of fluxing properties, but now include some sedimentary clays of similar physical properties. Kaolins have a low air-shrinkage, low modulus of rupture, low bonding power, and their plasticity is commonly poor. They are used chiefly in the manufacture of high-grade white wares.

Ball-Clay—A ball-clay is a plastic white or nearly white-burning sedimentary clay of high refractoriness and bonding power. The air- and fire-shrinkage is frequently high. Ball-clays are used chiefly in the manufacture of white ware to increase the plasticity, bonding strength and density after firing.

Fire-Clay—A fire-clay is highly refractory, fusing above cone 27, of variable plasticity, porosity, shrinkage, transverse strength, and color and has a low percentage of iron, alkalies, lime, magnesia, and titanium.

Stoneware-Clay—A stoneware clay is of good plasticity, medium to high transverse strength, fair toughness, and should burn dense at a comparatively low temperature (cones 6-8). Its color is rather important but is preferably gray, cream or buff. It should be fine-grained, of smooth, even texture, and should have a low shrinkage and good vitrifying qualities. Most modern stoneware, however, is made from a blend or mixture of several clays. Stoneware clays are also often used in the manufacture of other types of products, as art ware, earthenware, roofing tile, and terra-cotta.

Terra-Cotta Clays—Clays for this purpose should be semi-refractory, of fair plasticity, high transverse strength, high bonding power.

They should be dense-burning, have a low shrinkage, and be free from warping. The absence of soluble salts is an essential property. Most terra-cotta is made from a blend of several clays and is commonly fired at about cone 6 or 8. Gray or buff-burning fire clays are commonly used, but in most cases an artificial color is applied to the surface of the ware.

Sewer-pipe Clays—Clay for sewer-pipes should have a low shrinkage, high strength, and be free from warping and cracking. It should be vitrified, hence a clay high in fluxes is best, but at the same time it should have a long firing range. Vitrification should be reached at cone 3 or 4, but some clays used vitrify at a lower temperature. This type of ware is commonly covered with a salt glaze. Clays suited for sewer-pipe manufacture are similar to those used for paving brick. A dark-colored sewer pipe is most commonly called for on the market.

Brick Clays—Clay for common brick is usually impure, often sandy, high in fluxes, of medium plasticity, variable strength, color and porosity. They are in most cases red-burning but sometimes gray, cream, buff, or yellow. Common brick-clays are widely distributed.

Face brick, or sometimes called front or pressed brick, requires a better grade of clay than common brick. They must have a uniformity of color in burning, freedom from warping or splitting, absence of soluble salts, good hardness after firing and low porosity. The shrinkage and transverse strength are variable. Front brick may be red, white, cream or buff after firing. Such clays are commonly fired from cone 1 to 9. Clay for face brick should be more plastic than that for common brick so that the ware may retain its form better and present smooth faces and square corners. Plasticity, however, is not an important factor in dry-press methods. The clay should have a good firing range and should be burned so hard that it cannot be scratched with a knife.

Clay for paving brick should have the same general properties required of a sewer-pipe clay. Ordinarily such clay is burned to the point of vitrification but from some clays the toughest product is obtained before vitrification is reached. Such clays should have fair plasticity and good transverse strength. The firing range should be at least 150° C.

Hollow block, fire proofing, and drain tile all require clay of the same characteristics; in fact, they may all be made from the same kind of clay. The properties of clay suitable for these products is quite variable. They should have a fair transverse strength, burn to a hard but not vitrified body at a comparatively low cone (03-1), and should have sufficient plasticity to flow smoothly through the peculiar shape of die necessary to form them.

Slip-Clays—A slip-clay is one used as a natural glaze. It should be of fine, even texture, have a high percentage of fluxing impurities, and should melt to a greenish or brown glass at a low cone.

Miscellaneous—Clays used when burned, not included in the above mentioned groups, are: Gumbo-clay, having a high shrinkage, dense character, and fine grain, is used extensively as railroad ballast. Sagger-clay is used in making the saggers or boxes in which white ware and other high grades of pottery are burned to protect them from the flame and fuel gases. Their refractoriness must be above that of the product burned. Wad-clay is a low grade of fire clay used for sealing the joints between saggers when they are set in the kilns. Portland cement clay is that used in the artificial mixture of silica, alumina and lime which composes Portland cement. Clay or shale usually supplies the silica and alumina and limestone or marl the lime. The adaptibility of a clay for Portland cement can only be determined from a chemical analysis.

Many clays are used in the unburned condition as paper fillers, paint pigments, abrasives, etc.

USES OF CLAY

The uses of clay are many and varied and any attempt to list all of them would be hopeless. The following uses listed by Ries[1] summarizes those of raw clay as well as those of the fire or burned clay:

Domestic—Porcelain, white ware, stoneware, yellow ware, Rockingham ware for cooking and for table service, majolica stoves, polishing brick, bath brick, fire-kindlers.

Structural—Brick, common, front, pressed, ornamental, hollow, glazed, adobe, terra-cotta, roofing tile, glazed and encaustic tile, drain tile, paving brick, chimney flues, chimney pots, door knobs, fireproofing, terra-cotta lumber, copings, fence posts.

Refractories—Crucibles and other assaying apparatus, gas retorts, fire-brick, glass pots, blocks for tank furnaces, saggers, stove and furnace bricks, blocks for fire boxes, tuyeres, cupola molds, mold linings for steel castings.

Engineering—Puddle, Portland cement, railroad ballast, water conduits, turbine wheels, electrical conduits, road metal.

Hygienic—Urinals, closet bowls, sinks, washtubs, bathtubs, pitchers, sewer pipe, ventilating flues, foundation blocks, vitrified bricks.

Decorative—Ornamental pottery, terra-cotta, majolica, garden stands, tombstones.

Minor Uses—Food adulterant, paint fillers, paper filling, electric insulators, pumps, fulling cloth, scouring soap, packing for horses' feet, chemical apparatus, condensing worms, ink bottles, ultramarine manufacture, emery wheels, playing marbles, battery cups, pins, stilts, and spurs for potters' use, shuttle eyes and thread guides, smoking pipes, umbrella stands, pedestals, filter tubes, caster wheels, pump wheels, electric porcelain, food rules, plaster, alum.

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[1]Ries, H., Clays, Their Occurrence, Properties and Uses, p. 252, 1908.

To this list of clay products should be added turpentine cups, which are very extensively used in Florida. R. M. H.

CHAPTER VII
GEOLOGY OF THE CLAYS OF FLORIDA

STRATIGRAPHY

The formations exposed at the surface in Florida are all of the younger periods, ranging from Eocene to Recent, as may be seen from the accompanying table. Each period of the territory is represented and each contains clay to a greater or less extent.

TABLE OF GEOLOGIC FORMATIONS IN FLORIDA

ERA	PERIOD	FORMATION	THICKNESS	LITHOLOGIC DESCRIPTION	REMARKS
Quaternary	Recent	Recent	?	Sands and Clays	
	Pleistocene	Palm Beach Limestone	?	Marine Limestone	Exact stratigraphic relation undetermined
		Miami Oolitic Limestone	?	Marine Limestone	
		Key Largo Limestone	?	Marine Limestone	
		Key West Limestone	?	Marine Limestone	
		Lostmans River Limestone	?	Marine Limestone	
		Fort Thompson Beds	?	Freshwater and Marine Beds	
Tertiary		Lafayette Formation	?	Sands, Gravels and Clays	
	Pliocene	Citronelle Formation	?	Sands, Gravels and Clays	Largely Contemporaneous
		Bone Valley Formation	?-100′	Pebble Phosphate, Gravel, Clay, Sand	
		Alachua Clay Formation	100+	Non-Marine Clays	
		Caloosahatchee Formation	0-100′	Marine Marls	
		Nashua Marl Formation	0-100′	Marine Marls	
		Charlton Marl Formation	?	Marine Marls	
	Miocene	Choctawhatchee Formation	20′-50′	Chiefly Marls	Contemporaneous
		Jacksonville Formation	?	Limestone, Clay	
		Alum Bluff Formation	100′-200′	Sand, Gravel, Clay, Limestone, Fuller's Earth	
	Oligocene	Tampa Formation	?	Limestone, Clay	Contemporaneous
		Chattahoochee Formation	100′-200′	Impure Limestone, Clay	
		Marianna Formation	30+	Limestone	
	Eocene	Ocala Formation	20′-50′	Limestone	

EOCENE

The Eocene is represented by the *Ocala* formation which is exposed chiefly on the western side of peninsular Florida from Pasco to Lafayette counties and also in the northwestern portion of the State in Jackson

and Holmes counties. It consists chiefly of a soft, white, granular limestone which is locally silicified. Its thickness rarely exceeds fifty feet. A thick mantle of surface sands overlies large areas of this formation on its westward margin.

OLIGOCENE

The Oligocene is represented by three formations: the Marianna, the Chattahoochee, and the Tampa.

The *Marianna* formation is a soft, light-colored, granular limestone occurring only in a small area in the northwestern part of the State in the vicinity of Marianna and Cottondale in Jackson County. The formation as it occurs in this area is rather thin, slightly over thirty feet, but its upper portion has probably been removed by erosion.

The *Chattahoochee* formation is a soft, impure argillaceous or clayey limestone extending through portions of Suwannee, Hamilton, Madison and Jefferson counties south of the Georgia-Florida boundary and also farther westward in Gadsden, Jackson and Holmes counties. In the region west of the Apalachicola River the Chattahoochee limestone is overlain by a mantle of impure, sandy clay of variable thickness and reddish or yellowish in color. This in turn grades, at times sharply, into a gray-jointed clay below. These clays are probably residual from the Chattahoochee limestone. The thickness of the Chattahoochee formation ranges from 100 to 200 feet.

The *Tampa* formation is a hard silicious limestone occurring at the head of Tampa Bay and extending northwestward through Hillsborough, Pasco and Hernando counties. It is probably to some extent contemporaneous with the Chattahoochee formation.

MIOCENE

The Miocene period in Florida is represented by the Alum Bluff formation, the Jacksonville formation and the Choctawhatchee formation.

The *Alum Bluff* formation consists of sands, clays, sandy limestones, etc., deposited under both terrestrial and marine conditions. It contains much phosphatic material and perhaps all of the fuller's earth deposits of the State. It extends from the northern side of the Everglades and the Manatee River northward through the central portion of the peninsula to the Georgia-Florida boundary, thence west-

ward, in a somewhat broken succession in Florida, to almost the extreme west end of the State. It is probably the most widespread formation exposed in the State.

The *Jacksonville* formation is a term applied to deposits known in the vicinity of Jacksonville and having a limited extent. Its fauna indicates a later age, but otherwise it closely resembles the Alum Bluff formation.

The *Choctawhatchee* formation consists of marls, sands, and clays exposed in portions of west Florida.

PLIOCENE

To the Pliocene are assigned several formations consisting essentially of marls, sand and clays representing marine and fresh-water conditions of sedimentation. Several of these formations are probably contemporaneous.

PLEISTOCENE

The Pleistocene deposits, which here includes those of Recent age, as well, are of widespread distribution and variable lithologic character, representing both terrestrial and marine conditions. They are found principally in the southern extremity of the State and along both the Atlantic and Gulf coasts. Numerous deposits of this age, while relatively thin, are widely distributed over the interior portions of the State.

GEOLOGIC AGE, OCCURRENCE AND DISTRIBUTION OF THE CLAYS

There is not space within the limitations of this report to treat exhaustively the geologic age of the clays of Florida. In reconnaissance work it is often difficult and at times impossible to ascertain the horizon to which a clay deposit should be assigned, owing to its frequently limited areal extent, lack of fossils and imperfect exposures. The geologic map issued with the Fourteenth Annual Report of this Survey (1922) has been largely conformed to in assigning clays to formations already established and somewhat widely distributed within the State. It is to be noted, however, that within an extended area of exposure of one formation there may be numerous deposits of a more recent age. This is particularly true in Florida where the great number of sink-holes, swamps, and small streams of low gradient have afforded conditions favorable for the formation of clay deposits. Sellards[1] has pointed out that the sinks pos-

[1]Sellards, E. H., The Relation of the Dunnellon Formation to the Alachua Clay, Sixth Annual Report, Florida Geol. Survey, p. 162, 1914.

sibly began to form in Florida during the late Miocene and continued actively through the Pliocene and Pleistocene to the present and that during the Pliocene the sink-holes, ponds, lakes and surface streams reached their abundant and typical development in Florida. Many of the sink-holes form lakes which receive sediments carried in from the surrounding areas. This sediment settles to the bottom, forming layers of clay, sand or an intimate gradation between the two with varying amounts of other materials, depending upon the character of the sediment carried in and the character of the currents within the lake. Clays formed in the flood-plain of streams or filling the channels of former streams are also of frequent occurrence in Florida. Deposits of these types may occupy an area underlain by one formation and except on a very detailed or large scale geologic map no differentiation between the two horizons will be made. Where the determining features of such deposits are evident the clay is termed lacustrine or a flood-plain clay, etc., as the case may be. There is moreover in Florida a vast mantle or coating of surface sand and sandy clays of variable thickness which probably is of residual character resulting from the alteration of surface materials. This mantle often masks the true character and extent of the underlying formations. Indeed, in some sections of the State, particularly in west Florida, literally hundreds of square miles appear to be covered with this material where it caps the hills as well as the lower areas. The clay content of this covering material is often quite high, at times giving it the appearance of a plastic joint clay. It is, however, unsuited for the manufacture of clay products.

The Ocala formation which, in Florida, is the sole representative of the Eocene Period, consists primarily of limestone. The limestone in places has been altered to flint and in other places has weathered into a residual clay. These residual clay deposits, as is characteristic of limestone residuals, are of variable depth and limited lateral extent. This formation occupies an extensive area on the Gulf side of the northern part of the peninsula extending through portions of Pasco, Hernando, Sumter, Citrus, Marion, Levy, Alachua, Columbia, Lafayette, and Suwannee counties. There are within this area numerous small outliers of younger surrounding deposits and also local areas of Pliocene to Recent lacustrine or fluviatile sediments. The Ocala limestone also

outcrops in Jackson and Holmes counties where again it forms local residual clay deposits. These residual clays are variable in their physical properties. They range in color from a gray or greenish-gray to a brown, tan or light buff. Sometimes this range of color will be found in a single deposit with the lighter colors at the bottom. They are usually fairly plastic though at times somewhat stiff at the surface, becoming more plastic with depth. In places they are quite sandy and at times contain flint and limestone fragments or calcareous or ferruginous concretions. Red or dark brown-burning clays are the rule, though buff ones are found. Most of these clays have a high air- and fire-shrinkage and also crack and warp badly in drying and burning. The resulting losses are high. The deposits range in depth from a few inches to as much as twenty feet, with a slight overburden, and in lateral extent often cover as much as sixty or eighty acres or more. Some of these clays found in eastern Levy and western Marion and Alachua counties are suitable for common brick. None of the Ocala clays are now being utilized.

The Marianna formation (Oligocene) is a thin limestone of limited extent in Jackson County. Some very small and local residual clay deposits occur in this area. They will not be treated here, however, on account of their insufficient size and their calcareous character.

The Chattahoochee formation, also of Oligocene age, occupies an area in the vicinity of the Suwannee and Aucilla rivers, a small area on the Ocklocknee River, and a belt in west Florida extending westward from the Apalachicola River to beyond the Choctawhatchee River. It consists essentially of a very impure, soft argillaceous limestone with some interbedded clays and marls. Residual clays result from the weathering of this formation and hence are frequently found in the areas where it is exposed. The clays interbedded with the limestone are usually calcareous, greenish to gray in color, break with a slight conchoidal fracture, are fairly plastic, but at times stiff and often very sticky. The residual clay resulting from the decomposition of the Chattahoochee limestone is a plastic joint clay containing some calcareous concretions and geodes. Numerous deposits of it are located in Suwannee and Hamilton counties, in western Gadsden County, and in Jackson and Holmes counties. None of the Chattahoochee clay is now being utilized, although brick plants have formerly been operated near

Aucilla in Jefferson County and at River Junction in Gadsden County. Some of the Chattahoochee residual clays may be looked on with favor for the manufacture of common brick.

The Tampa formation is likewise of Oligocene age and is considered to be contemperaneous with the Chattahoochee formation. It consists of a hard silicious limestone exposed at the head of Tampa Bay, westward to the Gulf, and northeastward through Pinellas, Hillsborough, Pasco and Hernando counties, with some outliers extending farther northward. The limestone is locally weathered to residual clay. Sedimentary clay is also widely distributed in this formation. Some of these clays, both sedimentary and residual, are suitable for common brick.

A brick plant now being operated at Brooksville is using a residual Tampa formation clay. The upper two feet of the deposit is dark brown and somewhat sandy. The lower member averages about eight feet in thickness and is of a very light color. The clay grades into a limestone at the bottom of the workings and contains numerous flint concretions and fragments in the lower portion. The contact between the upper dark clay and the lower white clay is well defined and probably represents a former water table.

Several abandoned brick plants have in the past used the Tampa clay. One of these, the Old Tampa Brick Co., worked an exposure on the Hillsborough River about five miles northeast of Tampa. This deposit had the following section:

White sand and soil (Pleistocene)	2 feet
Unconformity	
Light green plastic clay (Tampa)	10 feet

The clay contained numerous cherty concretions. This same clay is exposed in several places along the Hillsborough River, near Oldsmar on Tampa Bay, and at several points on the Gulf coast in the vicinity of Tarpon Springs.

The Tampa formation has a sedimentary light green plastic clay above the chief limestone horizon and another clay strata of similar character below the limestone. This lower clay was found to range from forty-one to sixty-four feet in thickness in wells drilled at the Tampa Water Works. The upper clay horizon is the one most frequently exposed and is the one formerly used in the manufacture of brick.

The Alum Bluff formation of Miocene age is probably the most widely distributed of any of the formations exposed in Florida, extending in a belt of variable width from northern Okaloosa County eastward to the northern part of the peninsula, thence southward to the Manatee River and the northern margin of the Everglades. It consists chiefly of interbedded sands, gravels, marls and clays, including the fuller's earth, each of variable thickness and extent. These sediments are often cross-bedded indicating conflicting currents. They represent terrestrial, fresh-water and marine shallow-water conditions of sedimentation. The clays are usually thin, sandy, and variable in lateral extent. The Alum Bluff formation doubtless represents conditions of sedimentation not very different from those in operation in Florida at the present time.

The fuller's earth deposits are confined to a limited area in Gadsden and Leon counties, a smaller area in Manatee County, and isolated deposits in Marion and Alachua counties.

Overlying much of the fuller's earth in Gadsden County are two strata of clay. A section in one of the Floridin Company's mines near Quincy shows the following:

Soil and surface sand	5 feet
Unconformity	
Clay, green, plastic	3 feet
Apparent unconformity	
Clay, greenish, sandy	8 feet
Fuller's earth	

An exposure on the highway about one mile east of Quincy, however, exhibits only one stratum of clay. This is greenish in color and plastic. In other localities the clays above the fuller's earth are absent. In the vicinity of Quincy this clay has formerly been used for the manufacture of common brick and is very suitable for that purpose.

In the vicinity of White Springs the Alum Bluff clays are prominent. At the bridge across the Suwannee River the following section was observed:

Sand and soil (Pleistocene)	6 feet
Unconformity	
Green, plastic, jointed clay	8 feet
Sand and marls	?

An exposure on the White Springs-Lake City highway, about two miles northwest of Lake City, exhibited the following sections:

Sandy soil	2 feet
Brown and gray sand with clay	3 feet
Gray clay	3 inches
White and green sandy clay	3 feet
Green plastic clay	6 feet plus

(Bottom of clay not exposed.)

A grayish-green jointed clay has been used in the manufacture of common brick in two localities in the vicinity of Lake City.

At Campville, in Alachua County, a clay which is probably of Alum Bluff age is now being used for a good grade of common brick. A section of this deposit is:

Soil and sand	3 feet
White sandy clay	7 feet
Red and gray spotted clay	16 feet
Red sandy clay	?

Green and grayish Alum Bluff clays are exposed in Hatchett Creek one mile northeast of Fairbanks. Phosphatic clays, greenish to gray, are also found near Riverview in Hillsborough County and along the Gulf coast north of Dunedin in Pinellas County. This latter area probably represents an isolated remnant of the Alum Bluff.

There is throughout much of the Alum Bluff region a superficial deposit of red sand and clay. This material consists of coarse quartz, sand, at times gravel, with a variable clay content which is often high. Small flakes of mica are also often present in large quantities. This material is extensively used for road metal in Lake, Polk, Orange and Marion counties in the peninsula and also in Leon, Gadsden and several other counties in west Florida. These deposits are only tentatively included in the Alum Bluff. It is exceedingly doubtful if this material is Miocene. Some of it is probably a residual mantle resulting from the weathering of Alum Bluff formations as well as other sediments. While much of it may have originally been Alum Bluff deposits it has been largely reworked by subsequent streams and currents. Its age may be regarded as still unsettled.

It is doubtful if any clays representing the Jacksonville formation are exposed. The clays of Black Creek below Middleburg and those underlying South Jacksonville may be of Jacksonville age, but it seems more likely that they are of recent deposition.

The Choctawhatchee formation, Miocene, underlies a limited area in west Florida extending through Leon, Liberty, Calhoun, Washing-

ton and Walton counties. It consists of a marl member which is overlain by a grayish clay. The clay ranges in thickness from about ten to approximately thirty feet. This clay is the southeastward extension of the Pascagoula clay which is exposed through portions of the Gulf states to Eastern Texas.

The Charlton formation is a marine Pliocene marl extending along the northwest side of Nassau County next to the St. Marys River. It is not known to be associated with clays.

The Nashua formation, also Pliocene, consists of interbedded marls and clays and occupies a small area in Volusia, Flagler and Putnam counties. The clays are usually of limited extent and frequently thin Some of these are calcareous and all are to some extent sandy. Many, however, may be used for structural materials. Several of these clays have formerly been used in the manufacture of common brick.

The Caloosahatchee formation, likewise a marine Pliocene marl, underlies a small area on the Pinellas peninsula on the west side of Tampa Bay, and a much larger area in the region of the Caloosahatchee River. A few calcareous clays accompany the marl.

The Bone Valley formation, Pliocene, occupies a limited area east of Tampa in Polk, Hillsborough, Manatee and Hardee counties. It is a fluviatile deposit chiefly noted for its pebble phosphate content and is extensively worked for phosphate in this region. It also contains a sandy clay known throughout this region as the Bartow clay. This term was formerly applied to the matrix carrying the pebble phosphate, but now the application of the term is limited to the sandy clay overlying the phosphate horizon. The Bartow clay is widely distributed in this region and is used to some extent as a road-surfacing metal. Its high sand content greatly reduces its plasticity, making molding and handling difficult. When burned, however, it is suitable for common brick.

The Alachua clay is a terrestrial Pliocene formation composing small disconnected areas in central Florida. This term was formerly used to designate deposits of a blue to gray sandy clay which had accumulated in sinks and ponds during Pliocene times and encased numerous vertebrate remains. It is now understood to include also the hard rock phosphates formerly known as the Dunnellon formation. The Alachua clay formation contains many local clay deposits in Alachua, Levy and Marion counties.

The Citronelle formation, a Pliocene deposit extending through the Gulf states has only a limited extent in Florida. It extends through

portions of Escambia and Santa Rosa counties in the western extremity of the State. It is in most places overlain by Pleistocene deposits. An exposure which may be regarded as typical of the Floridian areas is seen at Dexland Bluff on the Escambia River east of Gonzales (see Fig. 10). The lower half of this section consists of interbedded gray, pink, buff and white micaceous clays intercalated with thin lentils of yellowish sand. This lower half is the Citronelle formation and is separated by an erosional unconformity as well as lithologically from the Pleistocene above. The Pleistocene consists of yellow and brown cross-bedded sands with some silt. Similar exposures exhibiting the same features may be seen at Gull Point, Red Bluff, and at Magnolia Bluff on Escambia Bay east of the city of Pensacola.

The clay deposits now being worked at Quintette and Molino are probably Citronelle. These are gray to brown in color, dense, and highly plastic. In the vicinity of Pensacola the Citronelle clays are thin and variable in lateral extent being interbedded, and even cross-bedded, with sands. These clays have been formerly used for stoneware in a pottery in Pensacola and are now being used in a pottery in St. Petersburg.

Citronelle clays are also exposed at several points northwest of Pensacola, near Muscogee and along the Perdido River.

Berry[1] says the physiography and vegetation during the deposition of the Citronelle sediments may be compared with that of the present time along the east coast of Florida north of latitude 28 degrees, or along the Gulf coast west of the Ocklocknee River. He says: "We may picture a more or less straight series of barrier beaches, probably with active sand dunes, a mile or more in width, and broken in places by inlets. Back of these beaches there were wide lagoons, of variable width, perhaps not less than a mile and certainly reaching a much greater width where some river expanded into a broad estuary, with its shallow and muddy bayous. The water in the lagoons varied from fresh to salt according to the presence or absence of inlets and the positions of the rivers."

The Lafayette formation (Pliocene) is not known definitely to exist in Florida, but some of the sands and clays of north and west Florida may represent this formation.

The beds of recognized Pleistocene age are the Fort Thompson Beds, Lostmans River Limestone, Key West Limestone, Key Largo

[1]Berry, E. W., The Flora of the Citronelle Formation, U. S. Geol. Survey Prof. Paper 96, p. 194, 1917.

Limestone, Miami Oolitic Limestone, and the Palm Beach Limestone, and are found in the extreme southern portion of the peninsula. No known clay deposits are associated with them.

There are many alluvial and lacustrine deposits of clay and clay-bearing sands throughout the State. These are principally Pleistocene and Recent, yet a few of them may have been formed during the Pliocene period. These undifferentiated deposits lie chiefly along the floodplains of the larger streams.

Extensive flood-plain deposits are found in the valley of the St. Johns River extending from Volusia County northward to Jacksonville. Many of these clays have never been worked and many more of them are capable of being utilized for various grades of structural materials. Former brick plants have been located near DeLand, DeLeon Springs, Denver, Palatka, Rice Creek, and Middleburg. Most of the clays found in this region are sandy, but some of great purity are found. Similar deposits are found in the vicinity of Kings Ferry. On the Ocklocknee River two brick plants (Ocklocknee Brick Co. and Tallahassee Pressed Brick Co.) now in operation, are using flood-plain clays. On the Apalachicola River several deposits of good quality are known and one of them is being worked at Blountstown.

The sedimentary kaolin found in several points in central Florida is of uncertain age. It will be discussed more fully in a subsequent chapter. Numerous lacustrine deposits will be discussed in the detailed description of deposits in the following chapter.

CONDITIONS OF SEDIMENTATION AND SOURCES OF MATERIAL

A complete geologic understanding of the clays of Florida involves a study of the geology of adjoining states. It also involves a review of the geologic processes that have been operating in Florida through the evidences by which these processes have been interpreted. Clay is always a secondary product; that is to say, it is always the result of decomposition and disintegration of pre-existing rocks. Igneous rock is the ultimate source of all other rock and therefore is the primary source of all clays.

No igneous rocks are known to occur in Florida and in view of the geologic conditions under which the Floridian land mass was formed, the probabilities of encountering igneous rock at any reasonable depth

are practically nil. The source of the material forming the clays and other sediments must be sought elsewhere.

During the Eocene and Oligocene periods the sediments were marine, representing shallow-water deposition and were formed probably while all of Florida and the coastal plain sections of Georgia and Alabama were yet submerged. These formations were deposited under conditions which were uniform over wide areas.

The Floridian peninsula partially emerged from the sea early in the Miocene period. Erosional forces set at once to rework and alter the configuration of the then existing surface. Solution of the underlying limestones and the resultant formation of sinks also began about this time, affording depressions for the accummulation of lacustrine deposits. Thus conditions very similar to those existing today began and have continued with but little change to the present time.

As deposits of transported clay may differ in thickness, character, and extent, according as the material has been deposited in flood-plains, lakes, swamps, estuaries or the open sea, corresponding variations are found in the Florida clays. Clays deposited in the shallow sea or tidal marshes are usually widespread and more uniform. Thus the Chattahoochee, Tampa and Choctawhatchee clays are fairly uniform over the areas they occupy. Under fluviatile and lacustrine conditions, on the other hand, variations in current and variations in the amount and character of the sediments carried resulting from erosional and climatic conditions, cause deposits of these types to differ widely in character. Thus the Alum Bluff, Citronelle and many Pleistocene deposits display marked irregularities.

The subsequent erosion and reworking of formations already deposited has been an important process in Florida. This accounts for the numerous isolated remnants or outliers of formations to be found in the State. The sedimentary kaolin deposits are an example of this condition. It also accounts for the presence of one distinct kind of material in two or more formations. Thus phosphatic material has been derived from the Alum Bluff formation, sorted and concentrated in later deposits to such an extent as to make mining profitable. This is also the origin of the Bartow clay.

The clays of Florida were derived either directly or indirectly from the crystalline rocks of the southern Appalachians exposed in Tennessee, North and South Carolina, northern Georgia and Alabama.

Material resulting from the decomposition and disintegration of this igneous and metamorphic rock may have been deposited in central Georgia and Alabama as Paleozoic, Mesozoic or Cenozoic sediments and a second time weathered and eroded away or it may have been transported directly by southward-flowing streams to the Florida area. Probably both conditions may be found. In any event, this material was carried in solution, in suspension in a finely-divided state, or mechanically rolled along by the stream currents. The quartz sand and gravel found in many of the clays was rolled along by mechanical processes, the mica and much of the colloidal matter was transported in suspension, and much of the lime, magnesia, iron, etc., was probably carried in solution. The prevailing drainage has been southward in the Southern States, hence most of the sediments in Florida have been derived from the northern areas. In the case of limestone residual clay the parent rock was deposited by precipitation of the calcium carbonate and the deposition of much of the impurities from suspension where it was being held in a finely divided condition. In the weathering of a pure limestone no clay would result, but as practically all limestones are more or less impure these insoluble impurities remain as clay when the calcium carbonate is dissolved out. Some of the Florida limestones are high in impurities, hence the resulting clay is quantitatively great.

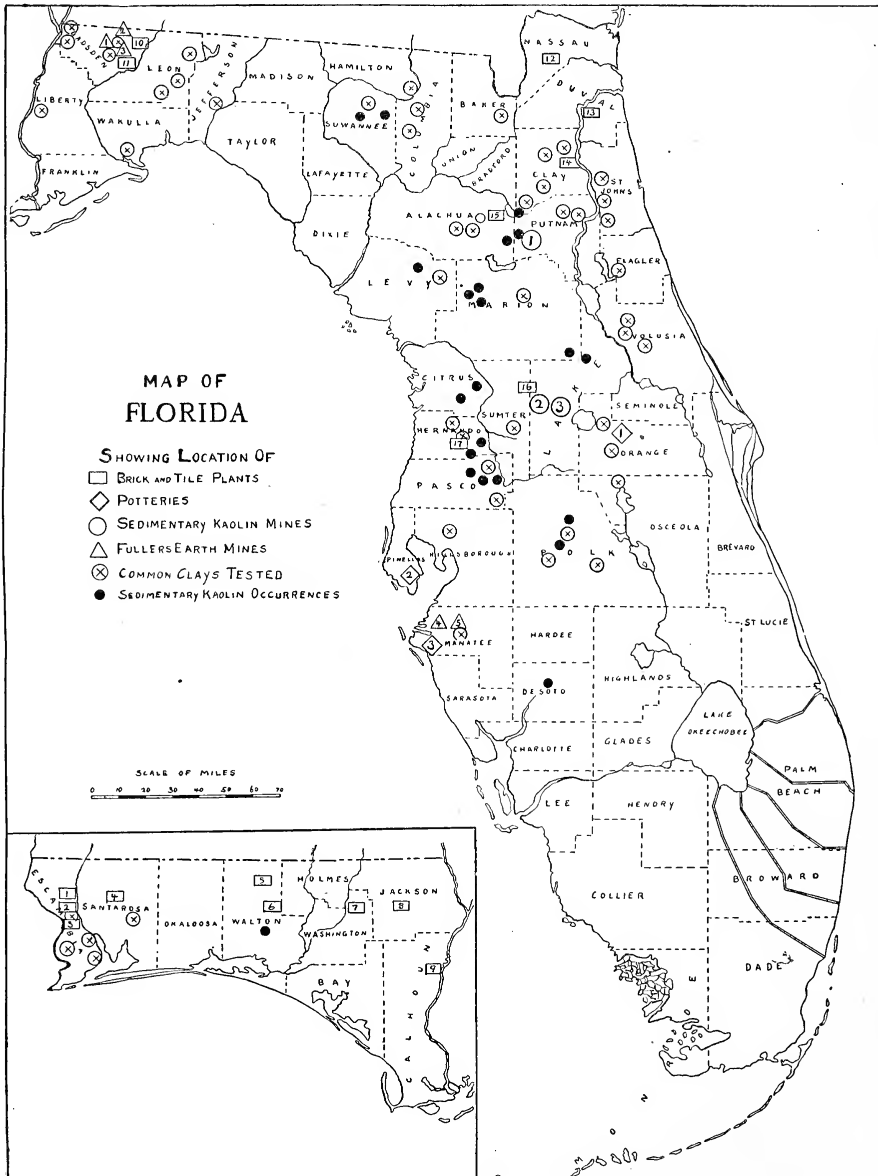

FIG. 2.
For explanation see opposite page.

KEY TO MAP (FIG. 2).

FULLER'S EARTH MINES.

1. Floridin Company, Quincy, Gadsden County.
2. Floridin Company, Jamieson, Gadsden County.
3. Fuller's Earth Company, Midway, Gadsden County.
4. Attapulgus Clay Company, Ellenton, Manatee County.
5. Manatee Fuller's Earth Corporation, Ellenton, Manatee County.

BRICK AND TILE PLANTS.

1. Macmillan Brick Company, Molino, Escambia County.
2. Dolores Brick Company, Molino, Escambia County.
3. Barrineau Brothers, Quintette, Escambia County.
4. Allentown Consolidated School, near Milton, Santa Rosa County.
5. Glendale Brick Works, Glendale, Walton County.
6. Murphy Brick Company, Argyle, Walton County.
7. Hall Brick Company, Chipley, Washington County.
8. Florida Industrial School for Boys, Marianna, Jackson County.
9. Guilford Brothers Brick Company, Blountstown, Calhoun County.
10. Tallahassee Pressed Brick Company, Havana, Gadsden County.
11. Ocklocknee Brick Company, Ocklocknee, Gadsden County.
12. Callahan Brick Company, Callahan, Nassau County.
13. Gamble and Stockton Company, South Jacksonville, Duval County.
14. Clay County Steam Brick Company, Green Cove Springs, Clay County.
15. Campville Brick Company, Campville, Alachua County.
16. Keystone Brick Company, Whitney, Lake County.
17. Morris and Blumer Brick Company, Brooksville, Hernando County.

POTTERIES.

1. Orlando Pottery, Orlando, Orange County.
2. Florida Pottery, St. Petersburg, Pinellas County.
3. Manatee River Pottery, Bradentown, Manatee County.

SEDIMENTARY KAOLIN MINES.

1. Edgar Plastic Kaolin Company, Edgar, Putnam County.
2. Florida China Clay Company, Okahumpka, Lake County.
3. Lake County Clay Company, Okahumpka, Lake County.

FIG. 3.—General View, Campville Brick Co., Campville, Alachua County.

CHAPTER VIII

DISTRIBUTION AND DESCRIPTION OF DEPOSITS BY COUNTIES

A description of the individual clay deposits with reference to their extent, properties and uses was not included in the foregoing account of the clay-bearing formations, inasmuch as the various deposits differ widely in their characteristics. The fuller's earth and "sedimentary kaolin" each occur in several localities in the State and a more detailed account of the occurrence of the latter is given in Chapter IX.

The various kinds of clay are not confined to any one geographical or political unit, but for convenience will be treated here by counties. The location of the active clay-working plants (including fuller's earth) is shown on the accompanying outline map (Fig. 2).

ALACHUA COUNTY

Alachua County is located in the north central part of the peninsula and the Alachua, Alum Bluff and Ocala formations occupy the greater part of its area. Numerous lacustrine and sink-hole deposits of uncertain age are also present, but are limited in extent. Clays are of widespread occurrence, but are usually sandy in character.

Coarse sandy clay suitable for sand-clay road metal is abundant in the eastern part of the county in the vicinity of Hawthorne. It ranges from five to fourteen feet or more in thickness and is overlain by a loose sand and soil overburden ranging from three inches to three feet in thickness.

Clay suitable for drain tile, hollow block, fireproofing and a good common brick is found underlying a rather extensive area in the region about Campville. Except for the color of the burned clay, which is pink at cone 010 and a dirty yellowish brown at cone 9, it would be desirable for face brick.

The Campville Brick Company's plant, located at about one-half mile north of Campville, uses this clay in the manufacture of common brick. The plant is located on the Seaboard Air Line Railway (Tampa Division), which offers shipping facilities to the principal points in south Florida. For a section of this pit see page 114.

The Campville brick is used to some extent for fire-box and furnace linings. It has a good refractoriness and withstands sudden changes

in temperature when in use fairly well without excessive losses from cracking.

A mixture of equal parts of the upper white clay and the lower reddish clay in this deposit as used by the Campville Brick Company has the following physical properties:

Physical Properties of Campville Brick Company Clay (Lab. No. 0-52).

Plasticity, judged by feel	Excellent.
Water of plasticity	27.45%
Pore water	2.55%
Shrinkage water	24.90%
Linear air shrinkage	11.5 %
Volume air shrinkage	28.3 %
Modulus of rupture, average	400.2 pounds per square inch.
Slaking test	24 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	14.69	33.20	Pink.
1050	0.5	15.81	33.60	Light pink.
1150	1.0	13.79	32.40	Light brown.
1190	1.0	13.66	30.20	Yellowish brown.
1230	1.0	12.40	29.40	Yellowish.
1310	1.0	13.28	30.10	Yellowish.

In the northeast part of the county in the region about Waldo and Melrose a brown sandy jointed clay is exposed in numerous places. It is only suitable for a low grade of common brick.

A blue-gray jointed clay is exposed in Hatchett Creek at the crossing of the Seaboard Air Line Railway (Cedar Key Division). This clay has an excessive air- and fire-shrinkage and cracks slightly in firing. It is of little value for fired products, except perhaps a poor grade of common brick. Its physical properties are:

Physical Properties of Hatchett Creek Clay (Lab. No. 0-47).

Plasticity, judged by feel	Poor.
Water of plasticity	39.30%
Pore water	3.08%
Shrinkage water	36.22%
Linear air shrinkage	15.5 %
Volume air shrinkage	44.7 %
Modulus of rupture, average	208.3 pounds per square inch.
Slaking test	2 minutes.

Steel hard at cone 1.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	6.5	8.42	20.50	Pink.
1050	7.5	9.57	21.75	Light brown.
1150	8.5	6.89	18.30	Dark brown.
1190	9.5	1.93	16.50	Brown.

A brown sandy clay occurs in numerous places in the region just west of Gainesville. Here the clay at times immediately overlies the Ocala limestone and at other times is underlain by a sand. It can only be used for a low-grade, soft, porous common brick. A common-brick plant was formerly operated about two miles northwest of Gainesville. A sample from the property of D. J. Richbourg, four miles southwest of Gainesville, has the following physical properties:

Physical Properties of D. J. Richbourg Clay (Lab. No. o-45).

Plasticity, judged by feel	Fair.
Water of plasticity	23.90%
Linear air shrinkage	4.5 %
Volume air shrinkage	22.55%
Modulus of rupture, average	255.4 pounds per square inch.
Slaking test	5 minutes.
Fire tests:	

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.0	15.07	36.10	Brick red.
1050	1.5	16.44	34.10	Brown.
1150	1.5	15.77	33.90	Brown.
1190	2.2	15.67	32.40	Chocolate brown.

Some residual clays from the Ocala limestone occur in the southwest portion of the county. These warp and crack badly and hence are practically unusable.

BAKER COUNTY

Baker County is located in the northeast part of the State. The surface materials consist of yellow and brownish sandy clays and sands, with the Alum Bluff formation underlying much of this loose material. The clays are of little value from a commercial standpoint. A clay which occurs about a half-mile southeast of Macclenny on the Maxville road was formerly used for common brick, but only a soft, porous, sandy common brick can be made from it. Its physical properties are:

Physical Properties of Macclenny Clay (Lab. No. o-61).

Plasticity, judged by feel	Excellent.
Water of plasticity	21.40%
Pore water	0.38%
Shrinkage water	21.02%
Linear air shrinkage	7.1 %
Volume air shrinkage	15.6%
Modulus of rupture, average	105.2 pounds per square inch.
Slaking test	1 hour.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.6	16.78	35.20	Pink.
1050	1.1	17.87	36.40	Light brown.
1150	1.1	17.34	36.10	Light brown.
1190	1.1	16.44	36.20	Pink.
1230	1.4	16.31	32.60	Pink.

BAY COUNTY

Bay County is located on the Gulf of Mexico in west Florida. The surface materials consist of sand and marl formations, both of which contain clay to some extent, but no deposits of sufficient purity to justify exploitation are known.

BRADFORD COUNTY

Bradford County is located in the northern part of the peninsula. The surface exposures in Bradford County include sandy clays and sands of uncertain age. Tests on three clays exposed on or near the State Prison Farm were made in 1914 by the Bureau of Standards,[1] but none of these, however, proved to be of any value for the manufacture of clay products.

BREVARD COUNTY

Brevard County is located on the southeast side of the peninsula. Sands, marls and shell beds comprise the surface formations, but no clays of any value are known at the present time. Some poor sandy clays occur west and southwest of Melbourne, but they are undesirable for clay products.

BROWARD COUNTY

Broward County is situated on the east side of the Everglades and was not included in the field work for this report. It is underlain chiefly by Pliocene and Pleistocene limestones, marls and sands.

CALHOUN COUNTY

Calhoun County lies immediately west of the Apalachicola River and is underlain by the Chattahoochee, Choctawhatchee and Alum Bluff formations in the northern part of the county. These formations contain a few local deposits of residual and surface clays. Undifferentiated sands and marls occupy the southern part of the county. Flood-plain

[1]Sellards, E. H., Report on Clay Tests for Paving Brick, Fla. Geol. Survey Press Bull. No. 7, 1915.

FIG. 4.—Clay pit. Guilford Bros. Brick Company, Blountstown, Calhoun County. The clay is allowed to weather for a time before being used.

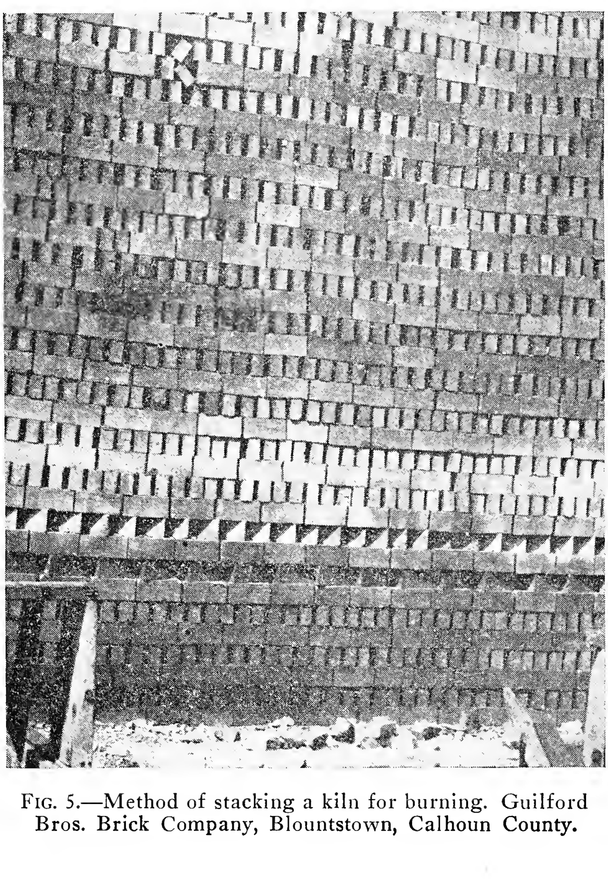

FIG. 5.—Method of stacking a kiln for burning. Guilford Bros. Brick Company, Blountstown, Calhoun County.

clays are common along the Apalachicola River, one such deposit being worked by the Guilford Brothers Brick Company at Blountstown.

The Guilford Bros. plant is situated about one-half mile south of Blountstown on a spur of the Marianna and Blountstown Railroad and about one-half mile from a barge landing on the Apalachicola River. Thus both rail and water shipping facilities are afforded.

The deposit is overlain by soil averaging about six inches in thickness and is underlain in places by sand. The deposit is somewhat lenticular, but averages from four to nine feet in thickness. The clay is dug away from the pit face, then heaped up and allowed to weather for an indefinite time. Sand and mica are present in this clay to a slight extent.

The clay is at present being used for the manufacture of common brick and at the time the field work was being carried on, brick from this plant was being used in the construction of the Post Office Building at Apalachicola. This clay may be used for face or common brick, drain tile, hollow blocks, flower pots, turpentine cups, ballast, etc. It has the following properties:

Physical Properties of Guilford Bros. Brick Company Clay (Lab. No. o-6).

Plasticity, judged by feel	Excellent.
Water of plasticity	29.75%
Pore water	0.93%
Shrinkage water	28.82%
Linear air shrinkage	9.7 %
Volume air shrinkage	32.20%
Modulus of rupture, average	421.7 pounds per square inch.
Slaking test	30 hours.

Steel hard at cone 1.
Overfires at cone 16.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	17.10	34.00	Brick red.
1050	0.3	18.20	34.60	Brick red.
1150	7.3	11.30	26.20	Brick red.
1190	7.3	6.50	18.50	Brick red.
1230	7.3	6.35	16.80	Brick red.
1310	7.8	4.23	16.40	Chocolate.
1370	7.8	3.42	13.10	Chocolate.
1430	7.8	3.82	14.40	Chocolate.

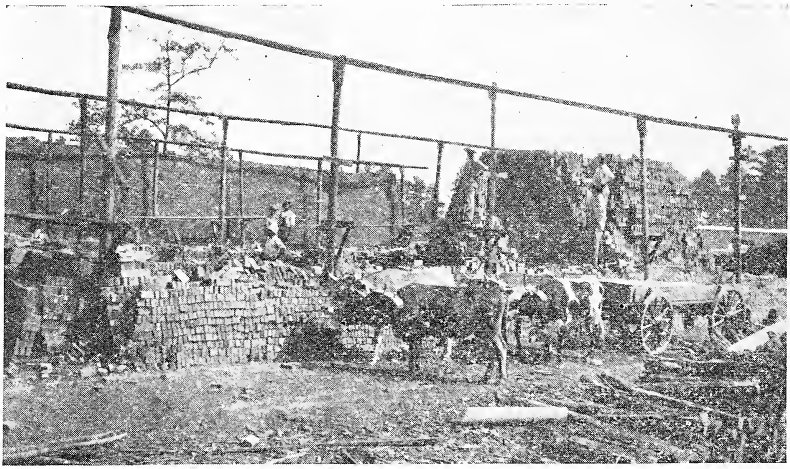

FIG. 6.—Unloading a kiln. Guilford Bros. Brick Company, Blountstown, Calhoun County.

CHARLOTTE COUNTY

Charlotte County is situated in south Florida west of Lake Okeechobee. Sands, marls and shell beds occupy the surface exposures, but no clay deposits are known at the present time.

CITRUS COUNTY

Citrus County is situated in the Hard Rock Phosphate region and is underlain mainly by Eocene and Pleistocene formations. Residual clays occur locally on the phosphate formations, but they are very irregular in thickness and extent and are subject to excessive cracking and warping in drying due to high air-shrinkage, hence are of no value for manufacturing purposes.

CLAY COUNTY

Clay County lies in the lower part of the St. Johns River valley and the eastern half of the county is extensively underlain by flood-plain clays. The western half of the county is covered by thick deposits of coarse sand with a clay content ranging from 15 to 40 per cent, much of which is suitable for sand-clay road metal. The St. Johns River valley clays have been used in numerous places for common brick, and one plant now operating at Green Cove Springs uses one of the flood-plain

FIG. 7.—Black Creek Barge Landing, near Middleburg, Clay County. Formerly used for shipping brick. Dismantled kiln may be seen on extreme right.

clays. Some calcareous and phosphatic clays occur in the southwestern portion of the county.

A clay exposed in the vicinity of Doctors Inlet in the northern part of the county and underlying several square miles between the Atlantic Coast Line and the St. Johns River has good dry strength and color, but has a high air-shrinkage. It may, however, be used for a good grade of common brick, drain tile, hollow blocks, etc. The exact thickness of this deposit was not determined, but is known to be over six feet in places. It is overlain by sand and loam ranging from one to two feet. A sample of this clay taken beside the Green Cove Springs-Jacksonville highway, about one-half mile east of Doctors Inlet station, has the following physical properties:

Physical Properties of Doctors Inlet Clay (Lab. No. o-50).

Plasticity, judged by feel	Excellent.
Water of plasticity	32.25%
Pore water	2.31%
Shrinkage water	29.94%
Linear air shrinkage	14.8 %
Volume air shrinkage	36.6 %
Modulus of rupture, average	504.2 pounds per square inch.
Slaking test	10 minutes.
Steel hard at cone 1.	
Overfires at cone 9.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.2	6.60	18.40	Brick red.
1150	2.7	5.69	17.10	Brick red.
1050	2.7	7.22	17.90	Brick red.
1190	4.2	3.69	17.20	Brick red.
1230	5.7	3.04	16.10	Brick red.

A clay similar to the Doctors Inlet clay is exposed on Black Creek about two miles east of Middleburg on the property of Frank Mooney. A brick plant formerly operated at this place was only abandoned about ten years ago and one kiln and parts of the dismantled machinery are still standing at the yard. This plant was located at a barge landing on Black Creek where tidewater shipping facilities are available. Shipment was formerly made by barge to Jacksonville and other points on the St. Johns River.

The clay pit is situated about one-half mile northward from the site of the plant. From six to ten feet of clay are exposed. This is overlain by from one to three feet of soil and sand. The clay underlies a part of the adjoining property owned by the Bryan Jennings Artesian Farm Land Company.

This Middleburg clay also has a high air shrinkage, but is suitable for face brick, common brick, drain tile and hollow ware. A sample taken from the unweathered portion of the old pit has the following physical properties:

Physical Properties of the Middleburg Clay (Lab. No. 0-78).

Plasticity, judged by feel............	Excellent.
Water of plasticity	27.90%
Pore water	2.07%
Shrinkage water	25.83%
Linear air shrinkage................	12.5%
Volume air shrinkage...............	41.5%
Modulus of rupture, average........	585.3 pounds per square inch.
Slaking test	10 minutes.

Steel hard at cone 010.
Overfires at cone 9.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	2.5	8.49	18.90	Brick red.
1050	3.5	2.82	9.65	Brick red.
1150	3.5	2.33	7.68	Gray.
1190	5.5	1.63	6.00	Gray.
1230	5.5	1.38	4.50	Chocolate brown.

The Clay County Steam Brick Company's plant located in the north edge of Green Cove Springs, works a deposit of gray and red mottled, plastic, slightly sandy clay, the presence of which has been proven under about thirty-five acres and probably underlies an even larger area. It varies from six to ten feet in thickness, has an overburden of loose sand and soil, and overlies a clean, white, sharp sand. The sand underlying the clay is used in cement and concrete construction work in Green Cove Springs. This clay is desirable for common brick and drain tile. A sample taken from the pit face as worked has the following physical properties:

Physical properties of the Clay County Steam Brick Company's Clay (Lab. No. o-43).

Plasticity, judged by feel	Excellent.
Water of plasticity	25.75%
Linear air shrinkage	10.02%
Volume air shrinkage	31.55%
Modulus of rupture, average	513.2 pounds per square inch.
Slaking test	1 hour.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	13.32	30.95	Grayish pink.
1050	0.2	14.31	31.50	Gray.
1150	0.2	11.89	28.50	Gray.
1190	0.3	11.96	28.45	Gray.
1230	0.8	11.06	22.75	Gray.
1310	0.8	11.03	20.50	Gray.

A clay collected by Mr. George T. Lloyd, from SE¼ Sec. 11, T. 7 S., R. 24 E., is suitable for soft, porous, common brick. Its physical properties are:

Physical Properties of Lloyd Red Burning Clay (Lab. No. o-64).

Plasticity, judged by feel	Excellent.
Water of plasticity	24.20%
Pore water	1.07%
Shrinkage water	23.13%
Linear air shrinkage	10.00%
Volume air shrinkage	30.20%
Modulus of rupture, average	565.4 pounds per square inch.
Slaking test	1 hour.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.0	14.01	33.00	Light brick red.
1050	0.5	15.03	32.50	Light brick red.
1150	1.0	11.72	28.75	Light brick red.
1190	1.0	11.21	28.20	Brown.
1230	1.5	10.60	25.10	Gray.
1310	2.5	10.50	29.50	Gray.

Another clay sent in by Mr. Lloyd from Sec. 2, T. 8 S., R. 23 E., contains much coarse, sharp angular quartz sand, but the sand content is not nearly so high as is the case in the sedimentary kaolins which occur in this general region. Mica is also present in small amounts. If washed, this clay would be suitable for some grades of white ware. The high porosity listed below is due to small cracks which developed in the test pieces during firing. A sample of the crude clay has the following physical properties:

Physical Properties of Lloyd White Clay (Lab. No. o-66).

Plasticity, judged by feel	Excellent.
Water of plasticity	21.50%
Pore water	2.85%
Shrinkage water	18.65%
Linear air shrinkage	9.3%
Modulus of rupture, average	120.4 pounds per square inch.
Slaking test	3 days.

Steel hard at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	3.2	32.07	48.80	White.
1050	3.7	32.97	48.75	White.
1150	3.2	29.67	45.10	White.
1190	3.2	29.60	46.00	White.
1230	3.7	30.09	45.65	White.
1310	8.7	19.60	37.10	White.
1370	12.2	12.53	28.75	White.
1410	14.7	9.38	21.20	White.

Still another white-burning clay sent in by Mr. Lloyd from Sec. 2, T. 8 S., R. 23 E., has a much greater percentage of sand and mica. It has the following physical properties:

Physical Properties of Lloyd Sandy White Clay (Lab. No. o-65).

Plasticity, judged by feel	Poor.
Water of plasticity	18.30%
Pore water	0.30%
Shrinkage water	18.00%
Linear air shrinkage	2.5%
Modulus of rupture, average	73.0 pounds per square inch.
Slaking test	2 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	17.90	37.50	White.
1050	1.5	17.04	37.60	White.
1150	1.5	17.49	37.20	White.
1190	1.5	16.90	35.25	White.
1230	2.0	16.85	32.60	White.

COLUMBIA COUNTY

Columbia County lies in the northeastern part of the State. The Alum Bluff formation is exposed at the surface in the northern two-thirds of the county and the Ocala formation in the southern one-third. Sandy surface clays of uncertain age cover a large part of the county. In some localities this material is desirable for sand-clay road material. South of the region about Lake City no clays of value are known as is also the case in the north and northeastern parts of the county. About six miles northeast of White Springs a very soft white shale is exposed on the Hamilton County side of the Suwannee River. For a detailed description of this exposure see page 165. This clay no doubt underlies adjacent portions of Columbia County as well.

A green jointed clay overlain by four feet of brown, gray and white mottled sandy clay is exposed about two miles south of Lake City on the Gainesville road. The contact between these two clays is indistinct and the upper portion is probably a residual mantle. The thickness of the lower clay is unknown. It has a high air shrinkage and cracks badly in drying and is therefore unsuited for use in manufactured products.

The region between Lake City and White Springs is underlain by one or more beds of a greenish jointed clay. These beds are variable in thickness and are interbedded with sands and sandy clays. In places this clay contains calcareous concretions and in other places it contains some phosphatic material, it has a high air shrinkage, warps and cracks badly, and its plasticity is too low to work satisfactorily in a stiff mud machine. For a typical section of this clay see page 114.

At a brick plant formerly operated about three miles southwest of Lake City a gray sandy clay occurs and was formerly used for common brick. Its low plasticity, low bonding strength and poor working qualities make it undesirable for any kind of manufactured clay product. It is still distinctly soft and porous at cone 15. It has the following physical properties:

Physical Properties of Lake City Brick Yard No. 1 Clay (Lab. No. 0-36).

Plasticity, judged by feel	Poor.
Water of plasticity	17.45%
Pore water	0.23%
Shrinkage water	17.22%
Linear air shrinkage	3.6%
Volume air shrinkage	7.92%
Modulus of rupture, average	121.0 pounds per square inch.
Slaking test	30 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.6	15.18	33.60	Cream.
1050	1.1	15.22	34.20	Cream.
1150	1.6	14.50	33.60	Cream.

Another brick plant was formerly operated about one-half mile north of Lake City where a sandy surface clay was used which likewise is undesirable for any burned product except a very low grade of common brick.

A bluish-gray clay occurs on the property of W. N. Cone about four miles north of Lake City on the Benton Road. Its plasticity is fair, its air shrinkage high, and its general qualities poor. It has, however, a high modulus of rupture, but is nevertheless undesirable for burned products. It has the following physical properties:

Physical Properties of W. N. Cone Clay (Lab. No. o-15).

Plasticity, judged by feel............	Fair.
Water of plasticity	41.20%
Linear air shrinkage................	14.7 %
Volume air shrinkage...............	46.2 %
Modulus of rupture, average........	1075.3 pounds per square inch.
Slaking test	15 minutes.

Steel hard at cone 010.
Overfires at cone 1.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	6.3	5.54	25.75	Brick red.
1050	7.8	4.80	24.25	Brick red.
1150	8.3	3.58	22.25	Brick red.

DADE COUNTY

Dade County is situated in the extreme southern portion of the State and its surface formations consist of limestones, sands and marls. No clays of importance are known.

DE SOTO COUNTY

De Soto County lies in the south central portion of the peninsula. The surface materials consist of sands, marls and sandy clays. Good sand-clay road material is abundant in the northern part of the county. A white clay high in lime and magnesia occurs a few miles northwest of Arcadia and extends northwestward through Manatee County to the vicinity of Bradentown. Its lime content gives it a short firing range

and makes it worthless for burned products. For its physical properties see Lab. samples Nos. 0-19 and 0-72 under Manatee County, page 184.

The Bartow clay is exposed in the northern portions of the county. See page 195 for a detailed description of the Bartow clay, Lab. Sample No. 0-53.

DIXIE COUNTY

Dixie County lies in northern Florida and adjoins the Gulf of Mexico. No clays other than very loose sandy ones are known in this County.

DUVAL COUNTY

Duval County is situated in the lower St. Johns River valley. Some sandy clays suitable only for sand-clay road material occur in the extreme southwest corner of the county along the Trail Ridge. Flood-plain clays are common along the St. Johns River and several of these have been worked in the past for common brick, while one plant at South Jacksonville is now engaged in the production of structural materials from two beds of these clays.

Two clays are exposed in the Gamble and Stockton Brick and Tile Company's plant at the end of Hendricks Street in South Jacksonville. A section of the deposit is as follows:

Sand, loose, brown	2 feet
Clay, red mottled	8 feet
Sand, white	2 feet
Clay, blue, very plastic	10 feet plus

The exact depth of this lower clay is not known as the workings have not reached the bottom. The loose brown surface sand at the top of the section is removed by a scraper. The white sand is mixed with the red and blue clays to reduce shrinkage and the two clays are used in equal proportions.

This deposit is now being used for the production of common and face brick, interlocking hollow block tile, and drain tile. The ware is molded in a stiff mud end cut machine and burned at cone 3 in circular down-draft kilns. Seger cones are used to indicate the progress of burning.

FIG. 8.—Clay pit. Gamble and Stockton Brick and Tile Company, South Jacksonville, Duval County. Two different beds of clay separated by a layer of sand are exposed in this pit.

The upper red mottled clay has the following physical properties:

Physical Properties of Gamble and Stockton Upper Red Clay (Lab. No. o-58).

Plasticity, judged by feel............	Excellent.
Water of plasticity	23.20%
Pore water	1.25%
Shrinkage water	21.95%
Linear air shrinkage................	8.7 %
Volume air shrinkage...............	24.2 %
Modulus of rupture, average........	608.7 pounds per square inch.
Slaking test	1 hour.

Steel hard at cone 9.
Overfires at cone 12.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.2	14.58	32.40	Brown.
1050	1.2	15.43	33.00	Brown.
1150	1.3	14.73	32.60	Brick red.
1190	1.3	13.32	32.00	Brick red.
1230	1.3	12.61	27.40	Brick red.
1310	1.5	12.63	26.60	Brick red.

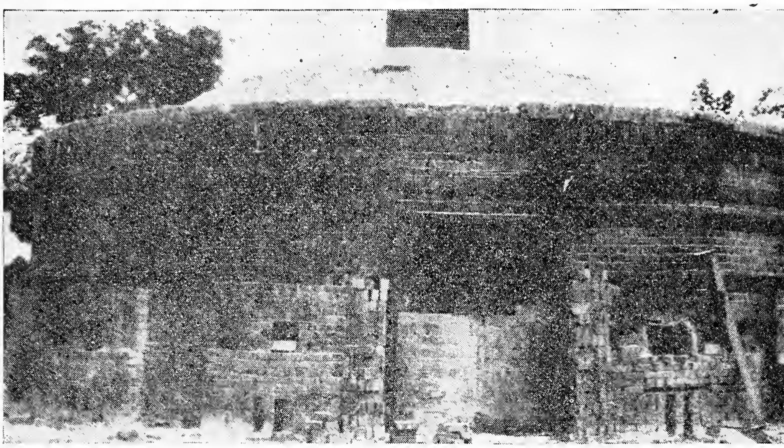

FIG. 9.—Circular down-draft kiln. Gamble and Stockton Brick and Tile Co., South Jacksonville, Duval County.

The lower blue clay has an extremely high modulus of rupture. It has a high air shrinkage which is a disadvantage, but on the other hand it dries easily without warping and cracking. It alone can be used for face brick, hollow blocks, roofing tile, drain tile, etc. It has the following physical properties:

Physical Properties of Gamble and Stockton Blue Clay (Lab. No. 0-32).

Plasticity, judged by feel............	Excellent.
Water of plasticity	30.50%
Pore water	0.51%
Shrinkage water	29.99%
Linear air shrinkage................	13.0 %
Modulus of rupture, average........	1593.1 pounds per square inch.
Slaking test	1 hour.
Steel hard at cone 05.	
Overfires at cone 12.	
Fire tests:	

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	13.95	20.75	Brown.
1050	4.0	7.91	20.40	Brick red.
1150	9.0	5.26	19.80	Brick red.
1190	4.0	3.50	15.30	Brick red.
1230	9.0	3.25	14.20	Brick red.
1310	4.5	1.94	13.20	Brick red.

A brownish, sandy surface clay from the Platt Bros. brick plant, now abandoned, about two and one-half miles east of South Jackson-

ville, was tested by the Bureau of Standards in 1914[1]. The results of these tests indicate that it may be used for face and common brick, hollow blocks, drain tile, etc. Its physical properties are:

Physical Properties of Platt Bros. South Jacksonville Clay, Bureau of Standards (Sample No. 11).

Plasticity	Good.
Water of plasticity	27.4%
Linear air shrinkage	6.2%
Fire tests:	

Temperature.	*Linear Shr. Per Cent.*	*Porosity. Per Cent.*	*Color.*
990°C.	0.05	28.1	Red.
1020		26.8	Red.
1050		25.7	Red.
1080		25.8	Red.
1110	0.827	24.8	Red.
1140		24.6	Red.
1170		22.5	Red.
1200		22.5	Red.
1230	2.34	20.4	Red.
1260		16.6	Red.
1290		11.5	Red.
1320	3.97	7.5	Red.

ESCAMBIA COUNTY

Escambia County lies between the Escambia and the Perdido rivers in the extreme western end of the State. Its surface exposures are chiefly sands and clays of Pliocene and Pleistocene age. From the ceramic viewpoint this county is perhaps the most interesting one in the State; its clay deposits are numerous and widely distributed and these range in quality from common brick to stoneware and terra-cotta clays. Face and common brick, turpentine cups and some pottery are now being made from Escambia County clays and a pottery formerly located in Pensacola made jugs and other forms of stoneware from local deposits.

Clays from Escambia County have probably been known and used longer than any others in Florida. Clay from Pensacola was shipped to Josiah Wedgewood[2] in England in 1766 for experimental work in his pottery. Williams[3] states that brick were being manufactured in West Florida prior to 1827 and cargoes of them were being shipped

[1]Sellards, E. H., Report on Clay Tests for Paving Brick, Fla. Geol. Survey Press Bull. No. 7, 1915.

[2]Meteyard, Eliza, Life of Josiah Wedgewood, Vol. I, p. 471, 1865.

[3]Williams, John L., West Florida, p. 69, 1827.

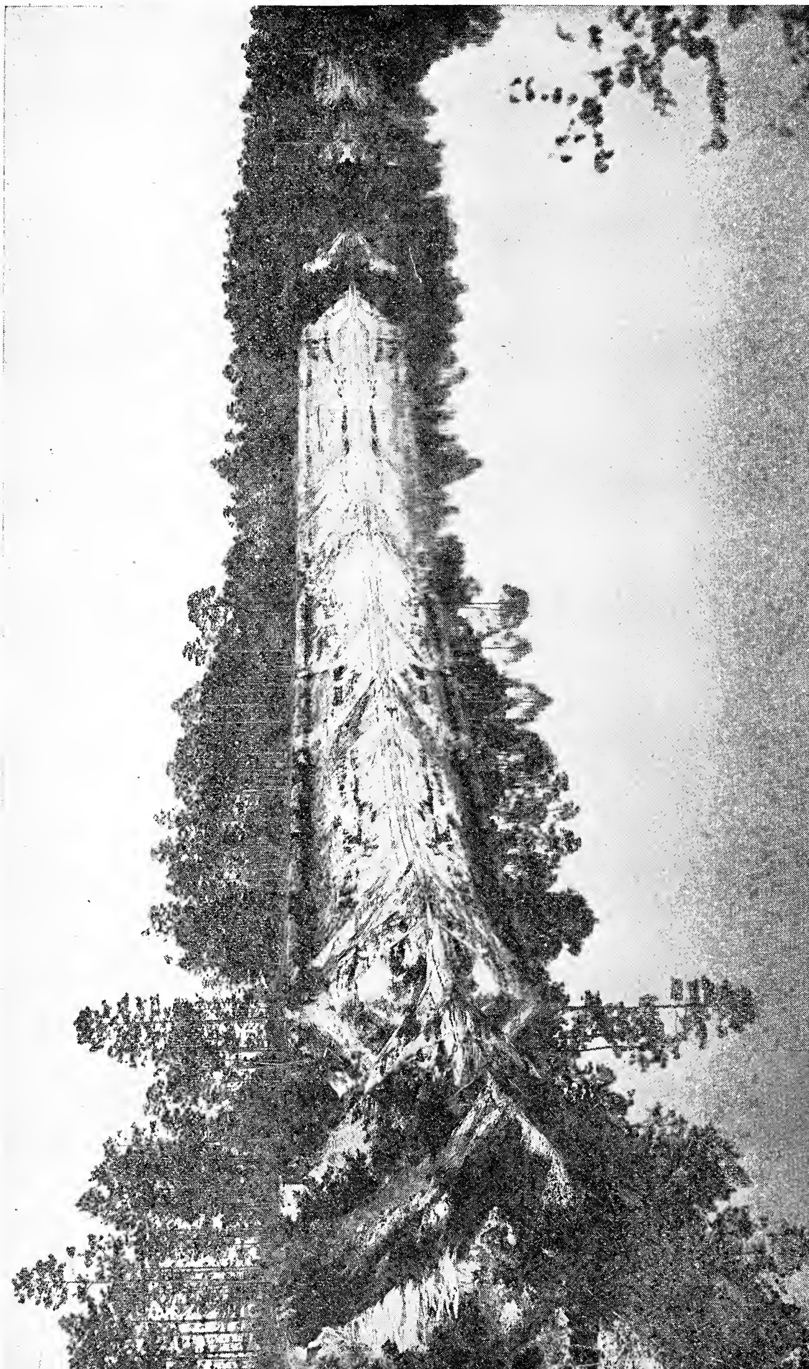

FIG. 10.—Bluff on west bank of Escambia River at Dexland, opposite Gonzales. Interbedded clays (Citronelle Formation?) in lower half of cliff; Pleistocene sands in upper half.—Courtesy of Chas. A. Dexter.

weekly to New Orleans from Pensacola. He also states that fire-brick in particular were in great demand and brought a very good price. The same author, writing in 1837[1], reiterated the same conditions.

Crary[2] made both mud and dry-press brick on Escambia Bay from 1856 to 1860 for the construction of Fort Jefferson on Dry Tortugas Island. He later established a brick plant at Bluff Springs in the northern part of Escambia County. The same author,[3] in writing of fire-clays, says "the best developed beds of fire-clay are found in Escambia County, Florida. In fact, the whole county is underlain with one vast indeterminable bed of potter's clay and fire-clay, in strata from six to forty feet deep, often cropping out on the surface. This clay is suitable for all kinds of pottery, for fire-brick, and for the very best kinds of building brick, or blocks for paving, and is cheap, accessible and in every way advantageously situated for profitable manufacturing." Crary, however, defines fire-clay as "antediluvial or primitive clay".[4] The term "primitive clay" is here applied to bedded deposits of clay which were not of flood-plain origin. This definition of a fire-clay is not now accepted and the clays of Escambia County referred to by Crary are not fire-clays.

The Citronelle formation underlies much of Escambia County and in most places is overlain unconformably by more recent sediments. Both the Citronelle formation and the undifferentiated Pleistocene sediments above consist essentially of lenticular, cross-bedded and interstratified sands and clays. Clays, however, form the greater part of the Citronelle section while sands prevail in the Pleistocene deposits.

An erosional unconformity separates the Citronelle formation from the Pleistocene. Other minor unconformities may be observed in numerous places. In a sand-clay pit about five miles north of Pensacola on the Flomaton road an unconformity occurs between two clays and is marked by a half-inch layer of limonite.

Layers of limonite, in places as much as six inches in thickness, are of common occurrence in several of the clay exposures where they mark the contact between two clays or between a sand and a clay. These limonitic layers probably represent zones of concentration formed from descending waters which have leached out the iron from the overlying

[1]Williams, John L., Territory of Florida, p. 114, 1837.
[2]Crary, J. W., Sr., Brickmaking and Burning, pp. 14 and 35, 1890.
[3]Same, p. 3.
[4]Same, p. 28.

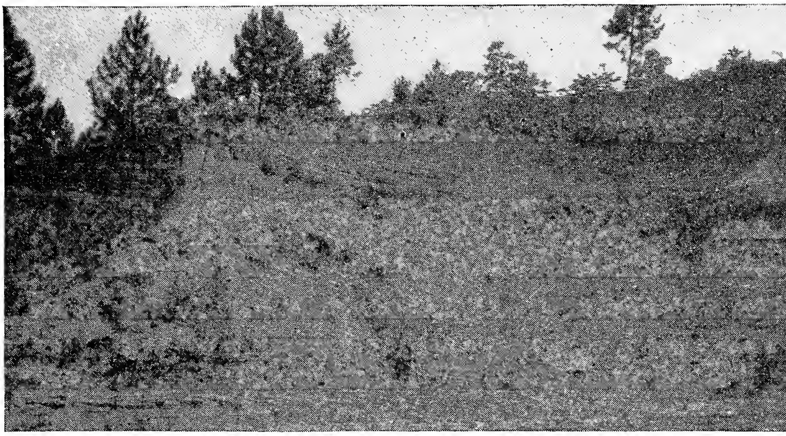

FIG. 11.—View of a pit face showing cross-bedded clays (probably Pleistocene). Dolores Brick Co., Molino, Escambia County.

FIG. 12.—General view of clay pit (Citronelle Formation?), Barrineau Bros. Brick Co., Quintette, Escambia County.

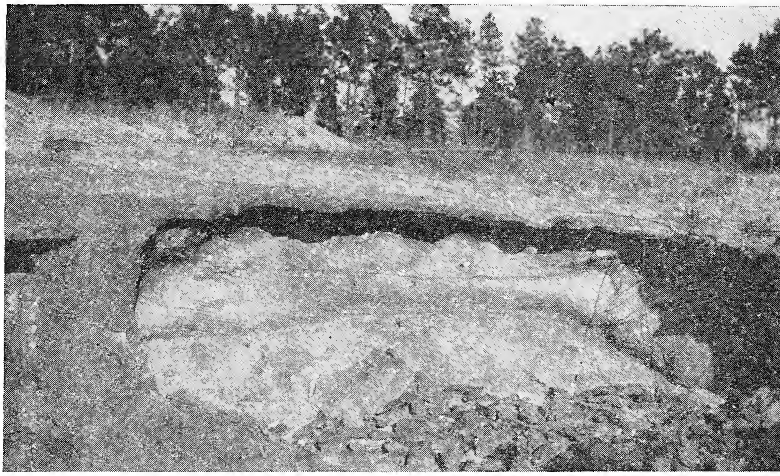

FIG. 13.—Layer of limonite overlying cross-bedded sand. The sand is underlain by clay. Barrineau Bros. Brick Co., Quintette, Escambia County.

ferruginous sediments and in places they may mark the upper limit of a former ground water table.

Chemical analyses of these clays are not available and therefore the iron content is not known, but if any is present, as is to be expected in clays associated with limonite, its coloring influence is surprisingly weak. Pink, cream, light buff and gray colors predominate and no typical red-burning clays are found, except in the case of those in the vicinity of Molino which are not apparently associated with limonite. Mica is present in small amounts in practically all of the Escambia County clays observed.

A sand-clay mantle, used locally for road material, overlies most of the county. Some of the clays are quite sandy and others are practically free from sand.

At Magnolia Bluff, Red Bluff and Gull Point, on Escambia Bay, and at Dexland Bluff on the Escambia River, several strata of clay are exposed which in their raw state are red, pink, or gray, but which have practically the same color and qualities when burned. Some of these strata are also exposed in a cut on the Gulf, Florida and Alabama Railroad about three miles east of Muscogee and near Eleven Mile Creek on the Pensacola and Alabama Railroad about eleven miles northwest of Pensacola. These clays range in thickness from a few inches to

twelve or fifteen feet and are interbedded with sands and sandy clays. Thin lentils of clay often appear in the sand. A given stratum of this clay may be distributed over a wide area, yet it may not be continuous throughout this region. Its thickness may vary and in places it may disappear altogether, owing at times to non-deposition, but in most places to subsequent erosion.

The following section at Gull Point will be illustrative of the general region, but it is to be noted that the intervals between the various strata are variable:

Section at Gull Point, Escambia Bay.

Soil	2 feet.
Clay, gray, jointed, Gull Point No. 1 (Lab. Sample No. 0-49)	4 feet.
Sand, cross-bedded, with some clay lentils	4 feet.
Clay, gray, very plastic, Gull Point No. 2 (Lab. Sample No. 0-2)	3 feet.
Sand, cross-bedded, with clay lentils	10 feet.
Clay, red, very plastic, Gull Point No. 3 (Lab. Sample No. 0-31)	4 feet.
Sand, cross-bedded, with some clay lentils	?

A boring made near Ninth Avenue and Marino Street in the City of Pensacola indicated the following section:

Section near Ninth Avenue and Marino Street, Pensacola.

Soil and sand	5	feet
Clay, gray, very plastic	4½	feet
Clay, red, plastic	6	inches
Clay, gray, sandy	4	feet
Clay, red, plastic	6	inches
Sand, red	8	inches
Sand, white	?	

This section was made at the site of the Kohler Pottery, formerly operated in Pensacola, and is only about two miles from the Gull Point section. The uppermost gray plastic clay was used in the manufacture of jugs and similar articles of stoneware. This bed is exposed about a half block northeastward in an excavation made by the city of Pensacola and corresponds in appearance and properties to the Gull Point clay No. 2 (Lab. Sample No. 0-2) and is probably the same stratum. The Gull Point clay No. 3 (Lab. Sample No. 0-31) is here split into two thin layers of six inches each separated by a coarse, gray, sandy clay four feet in thickness. Gull Point clay No. 1 is not exposed here.

At Dexland Bluff, property of Chas. A. Dexter, on the Escambia River opposite Gonzales, about ten miles north of Pensacola, a similar

FIG. 14.—Pink pottery clay (Citronelle Formation?) exposed in bluff at Gull Point near Pensacola, Escambia County.

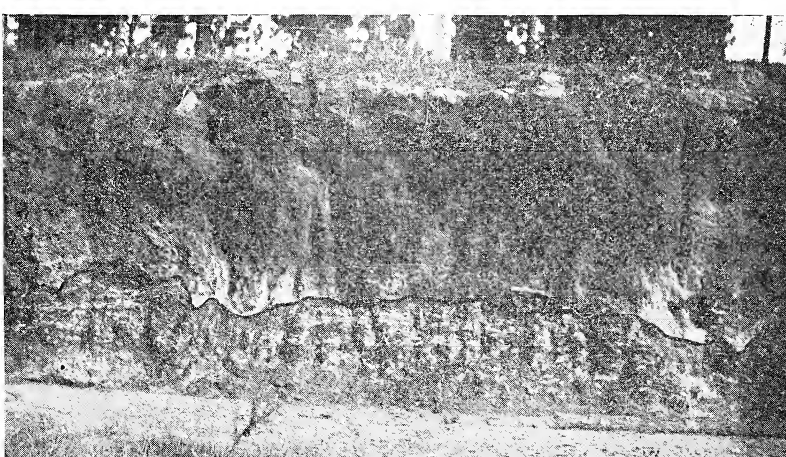

FIG. 15.—Unconformity between two clay beds exposed in a pit five miles north of Pensacola, Escambia County.

exposure is to be seen. There are two bluffs, each about 500 feet long and 65 feet above the river. The northern bluff is termed the Upper Bluff and the southernmost one the Lower Bluff. A generalized section made at the lower end of the Lower Bluff is as follows:

Generalized Section near South End of Lower Dexland Bluff.

Sand, cross-bedded with some clay lentils (Pleistocene)	30-35 feet
Unconformity, ercsional, separating Citronelle formation from Pleistocene	
Clay, gray sandy	10-15 feet
Clay, red, very plastic (Dexland No. 2, Lab. Sample No. 0-18)	6-8 inches
Sand parting	1-2 inches
Clay, gray, very plastic (Dexland No. 3, Lab. Sample No. 0-13)	2-4 feet
Sand, cross-bedded, containing coarse quartz pebbles	?

In this section Dexland clay No. 2 (Lab. Sample No. 0-18) very closely resembles the red clay at Gull Point (Gull Point No. 3, Lab. Sample No. 0.31), but contains a slight amount of sand.

The Upper Dexland Bluff has essentially the same section as the one just given, with an additional stratum about six feet above the river level consisting of a black plastic clay about six inches in thickness (Dexland No. 6, Lab. Sample No. 0-25).

At the upper end of the Lower Dexland Bluff is a ten-foot exposure of a gray mottled plastic clay (Dexland No. 1, Lab. Sample No. 0-82) which is probably the same as the Barrineau Bros. clay at Quintette (Lab. Sample No. 0-68) only six or seven miles farther up the river. It is here, however, not associated with limonite.

The qualities of these clays are similar, but their raw color, which is lost in firing, is variable. These clays are desirable for terra-cotta, stoneware, some grades of pottery and roofing tile.

From a commercial point of view, however, the clays exposed on Escambia Bay and at Dexland Bluff, on the Escambia River, offer very little. The beds are thin and variable and are overlain by a heavy overburden which is as much as forty feet in places. Some of these clays are now being used in a small pottery in south Florida which specializes in ornamental articles. The amount of clay needed for this kind of demand is not great and can be procured at natural exposures without extensive excavation.

Gull Point Clay No. 1, the gray jointed clay uppermost in the section and overlain by only about two feet of soil, has the following physical properties:

Physical Properties of Gull Point Clay No. 1 (Lab. No. 0-49).

Plasticity, judged by feel	Excellent.
Water of plasticity	22.95%
Pore water	0.15%
Shrinkage water	22.80%
Linear air shrinkage	7.3%
Volume air shrinkage	22.9%
Modulus of rupture, average	246.2 pounds per square inch.
Slaking test	24 hours.

Steel hard at cone 05.
Overfires at cone 16.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	6.7	18.58	35.75	Pink.
1050	7.3	17.90	34.40	Pink.
1150	7.0	12.38	28.00	Cream.
1190	7.2	12.25	23.60	Cream.
1230	7.1	12.54	23.00	Cream.
1310	7.4	9.41	22.20	Gray.
1370	8.2	6.49	21.30	Gray.
1430	8.2	2.85	13.00	Gray.

Gull Point Clay No. 2, the second clay stratum from the top of the section, has the following physical properties:

Physical Properties of Gull Point Clay No. 2 (Lab. No. 0-2).

Plasticity, judged by feel	Excellent.
Water of plasticity	31.75%
Pore water	0.93%
Shrinkage water	30.82%
Linear air shrinkage	8.3%
Volume air shrinkage	28.9%
Modulus of rupture, average	180.7 pounds per square inch.
Slaking test	1 hour.

Steel hard at cone 1.
Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.8	27.87	39.17	Pink.
1050	0.8	20.79	37.50	Pink.
1150	5.7	10.45	23.26	Gray.
1190	6.7	5.20	12.30	Gray.
1230	6.7	5.08	10.50	Gray.
1310	6.7	4.82	10.45	Gray.
1370	6.7	1.92	7.53	Gray.
1430	8.2	1.36	7.16	Gray.

Gull Point Clay No. 3 lies nearest the bottom of the section. It has a deep, reddish-pink color in its raw state, which it retains when fired at cone 05 but loses before cone 1 is reached. It has the following physical properties:

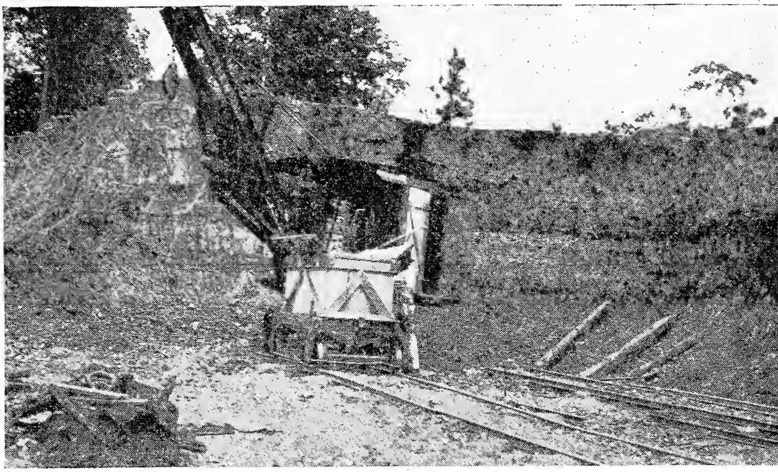

FIG. 16.—Mining clay with steam shovel, Dolores Brick Company Molino, Escambia County.

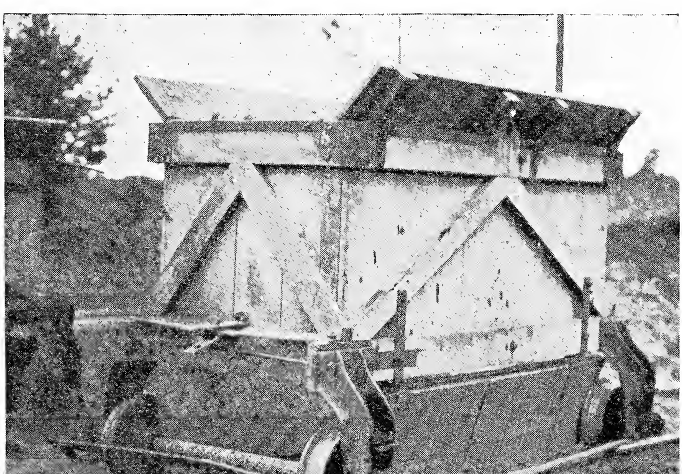

FIG. 17.—Dump car for conveying clay from pit to press. Dolores Brick Company, Molino, Escambia County.

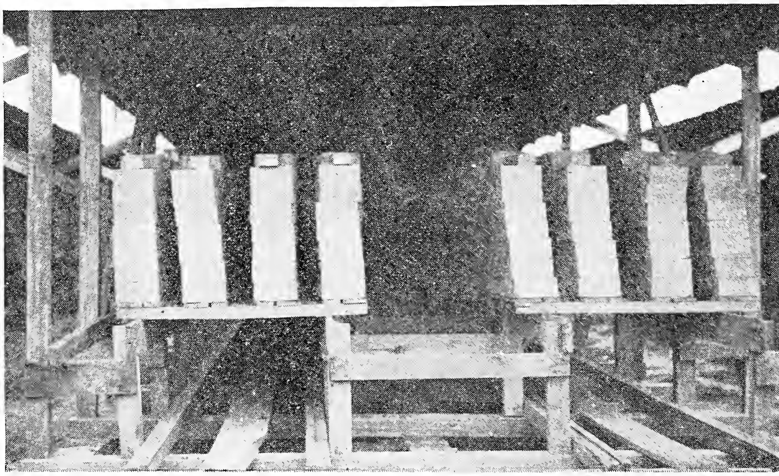

FIG. 18.—View of drying shed showing method of stacking brick for drying. Dolores Brick Company, Molino, Escambia County.

Physical Properties of Gull Point Clay No. 3 (Lab. No. 0-31).

Plasticity, judged by feel	Excellent.
Water of plasticity	32.25%
Pore water	2.61%
Shrinkage water	29.64%
Linear air shrinkage	9.7%
Volume air shrinkage	32.8%
Modulus of rupture, average	251.5 pounds per square inch.
Slaking test	1 hour.

Steel hard at cone 1.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.8	21.20	38.40	Reddish pink.
1050	2.0	20.10	36.70	Reddish pink.
1150	4.3	11.40	24.50	Chocolate brown.
1190	5.3	6.56	14.90	Chocolate brown.
1230	7.8	4.32	10.40	Chocolate brown.
1310	11.3	3.29	7.40	Chocolate brown.

Dexland Clay No. 2 is a thin stratum, six or eight inches, exposed in Lower Dexland Bluff. It has an appreciable amount of quartz sand. Its physical properties are:

Physical Properties of Dexland Clay No. 3 (No. Lab. 0-13).

Plasticity, judged by feel............	Excellent.
Water of plasticity	28.60%
Linear air shrinkage................	11.6 %
Volume air shrinkage...............	33.8 %
Modulus of rupture, average........	656.6 pounds per square inch.
Slaking test	2 days.

Steel hard at cone 010.
Overfires at cone 16.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.1	14.95	22.40	Pink.
1050	1.9	14.30	29.75	Pink.
1150	4.4	9.30	20.95	Buff.
1190	4.4	7.83	19.20	Buff.
1230	5.4	6.80	18.30	Cream.
1310	5.4	5.35	12.10	Cream.
1370	5.4	3.72	11.70	Gray.
1430	6.4	3.32	10.80	Gray.

Separated from the above clay by a thin sand parting is Dexland No. 3, which is a very plastic gray clay having the following physical properties:

Physical Properties of Dexland Clay No. 3 (Lab. No. 0-13).

Plasticity, judged by feel............	Excellent.
Water of plasticity	29.40%
Pore water	1.65%
Shrinkage water	27.75%
Linear air shrinkage................	10.6 %
Volume air shrinkage...............	38.4 %
Modulus of rupture, average........	475.0 pounds per square inch.
Slaking test	20 minutes.

Steel hard at cone 05.
Overfires at cone 16.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	16.80	33.65	Pink.
1050	0.6	18.40	32.25	Cream.
1150	6.4	12.25	18.00	Buff.
1190	6.4	4.15	19.45	Buff.
1230	6.4	2.58	10.10	Gray.
1310	6.4	1.22	5.40	Gray.
1370	6.9	3.05	5.25	Gray.
1430	4.4		6.75	Gray.

Dexland Clay No. 4 is a gray, slightly sandy clay, exposed in both the upper and lower bluffs. It is the uppermost clay stratum having an

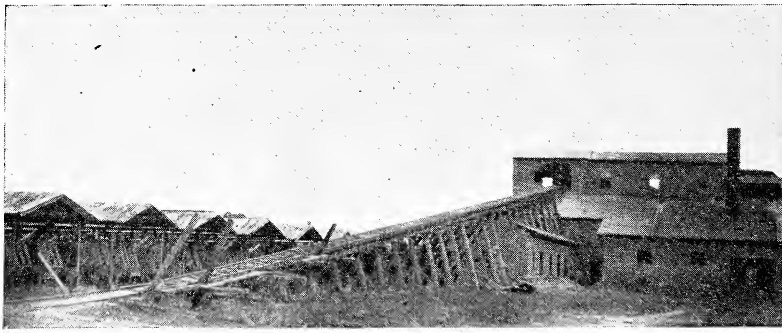

FIG. 19.—Plant and drying sheds, Dolores Brick Co., Molino, Escambia County.

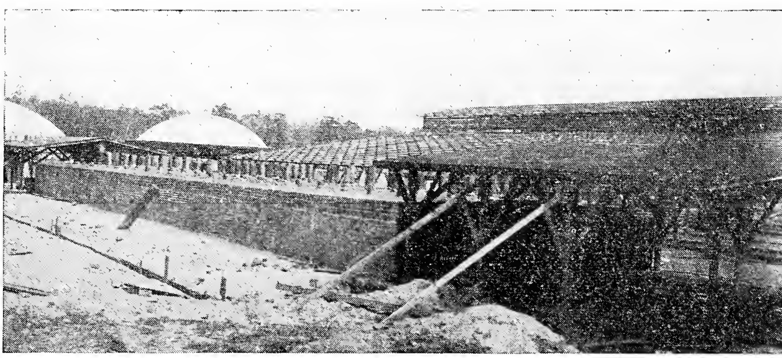

FIG. 20.—Drying tunnels. Macmillan Brick Company, Molino, Escambia County. Waste heat from kilns being fired is used to dry green brick.

FIG. 21.—A battery of circular down-draft kilns. Dolores Brick Co., Molino, Escambia County.

appreciable thickness and ranges from six to fifteen feet. It has the following physical properties:

Physical Properties of Dexland Clay No. 4 (Lab. No. 0-12).

Plasticity, judged by feel	Excellent.
Water of plasticity	25.20%
Pore water	1.37%
Shrinkage water	29.95%
Linear air shrinkage	8.5 %
Volume air shrinkage	19.4%
Modulus of rupture, average	207.9 pounds per square inch.
Slaking test	20 minutes.

Steel hard at cone 1.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.0	18.70	35.25	Cream.
1050	1.0	17.95	34.60	Cream.
1150	1.5	17.50	34.20	Cream.
1190	1.5	13.80	28.65	Cream.
1230	1.5	11.58	27.75	Cream.
1310	1.5	10.58	25.20	Cream.
1370	1.5	7.57	25.90	Brown.
1430	2.5	6.30	20.40	Brown.

Dexland No. 5 is a gray plastic clay ranging from six to ten feet in thickness and exposed about three feet above the river level at the upper bluff. Its physical properties are:

Physical Properties of Dexland Clay No. 5 (Lab. No. 0-73).

Plasticity, judged by feel	Excellent.
Water of plasticity	28.60%
Pore water	0.85%
Shrinkage water	27.85%
Linear air shrinkage	10.4 %
Volume air shrinkage	32.8 %
Modulus of rupture, average	384.4 pounds per square inch.
Slaking test	10 minutes.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.1	24.30	32.05	Cream.
1050	1.1	17.20	30.65	Cream.
1150	2.6	9.86	21.50	Brown.
1190	5.6	6.24	9.70	Brown.
1230	5.6	6.16	9.72	Gray.
1310	6.6	4.08	6.65	Gray.

Dexland No. 6 is an eight-inch layer of black plastic clay exposed about four feet above the river at the lower end of the Upper Bluff. Its

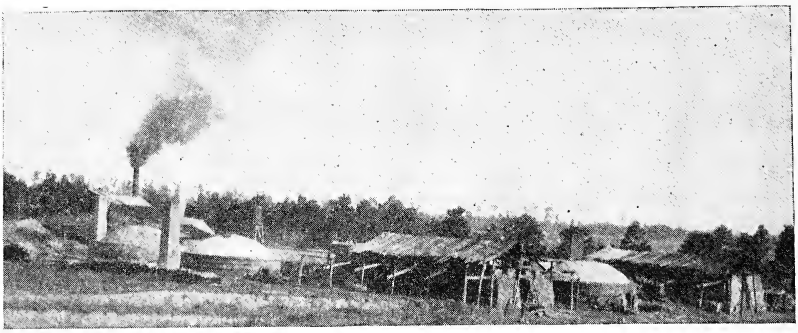

FIG. 22.—General View of Barrineau Bros. Brick Plant, Quintette, Escambia County.

black color is due to the presence of organic matter which is completely burned off, leaving it a light-cream color at cone 010. Its physical properties are:

Physical Properties of Dexland No. 6 (Lab. No. 0-25).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.90%
Pore water	0.40%
Shrinkage water	26.42%
Linear air shrinkage	10.8 %
Volume air shrinkage	31.0 %
Modulus of rupture, average	1021.1 pounds per square inch.
Slaking test	24 hours.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.8	16.22	40.50	Cream.
1050	2.2	16.56	31.75	Cream.
1150	2.2	12.80	27.50	Cream.
1190	3.2	7.82	17.50	Gray.
1230	3.2	7.95	17.80	Gray.
1310	3.2	6.84	16.90	Gray.
1370	4.2	4.72	12.95	Gray.
1430	7.7	3.62	10.20	Gray.

Clays having properties similar to the Dexland and Escambia Bay clays are also found farther westward in the valley of the Perdido River.

A reddish-pink, very smooth-textured, highly plastic clay occurs about three miles east of Muscogee in a cut on the Gulf, Florida and Alabama Railroad. The clay is cross-bedded and dips slightly to the westward. There are several strata alternating with thin beds of sand.

This clay is underlain by sand and sandy clay. The overburden ranges from one to six feet. This clay is free from sand, but contains small amounts of very fine mica flakes. Its physical properties are:

Physical Properties of Muscogee Cut Clay (Lab. No. o-4).

Plasticity, judged by feel	Excellent.
Water of plasticity	27.90%
Pore water	0.68%
Shrinkage water	27.22%
Linear air shrinkage	6.4%
Volume air shrinkage	18.2%
Modulus of rupture, average	214.3 pounds per square inch.
Slaking test	1 hour.

Steel hard at cone 1.
Overfires at cone 15.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.9	19.75	36.43	Pink.
1050	0.1	18.32	35.81	Pink.
1150	5.1	9.25	16.58	Buff.
1190	5.1	9.42	14.23	Buff.
1230	5.6	6.50	12.39	Cream.
1310	5.6	5.30	11.04	Cream.
1370	6.1	0.49	2.17	Gray.
1430	4.6	1.05	5.41	Gray.

On the property of I. L. Schaffer on the Pensacola and Alabama Railroad, about eleven miles northwest of Pensacola, is another exposure of a similar clay. This is gray and brown mottled, occurring in a very irregular deposit overlain unconformably by a cross-bedded sand. The clay underlies an extensive area in this locality, but is quite variable in thickness. In places it is as much as fifteen feet thick. It has the following physical properties:

Physical Properties of Schaffer Clay (Lab. No. o-40).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.15%
Pore water	0.18%
Shrinkage water	25.97%
Linear air shrinkage	8.3%
Volume air shrinkage	23.95%
Modulus of rupture, average	262.8 pounds per square inch.
Slaking test	30 minutes.

Steel hard at cone 05.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.8	19.23	35.40	Pink.
1050	1.7	19.90	33.10	Cream.
1150	1.7	19.45	29.75	Cream.
1190	2.7	11.30	24.20	Cream.
1230	2.2	10.10	24.60	Gray.
1310	4.2	7.72	21.50	Gray.
1370	4.7	5.39	16.90	Gray.
1430	6.7	1.72	4.85	Gray.

A dense, gray, plastic clay is of rather widespread occurrence in the region about Quintette. An extension or outlier of what is probably this same deposit is exposed at the upper end of Lower Dexland Bluff. It underlies both the hill just west of Quintette station and the one about one quarter-mile northward. It was also observed on the property of S. J. Baumeister, one-half mile west of Quintette. A section made at the Barrineau Bros. Brick Company's plant at Quintette is as follows:

Section of Barrineau Bros. Brick Company Clay Pit, Quintette.

Soil	3 feet.
Sand	3 feet.
Limonite	6 inches.
Clay	2 feet.
Limonite	2 inches.
Clay, gray, dense, plastic...........	30 feet plus (variable).
Limonite	3 inches (in places only).
Sand	? (in places only).

In many places the limonite overlies a cross-bedded sand.

The Barrineau Bros. Brick Company use this clay for the manufacture of face and common brick and turpentine cups. Their plant is located on the Pensacola Division of the Louisville and Nashville Railroad. The product is marketed chiefly in western Florida, southern Alabama, Mississippi and Louisiana. Mobile and Pensacola absorb the greater part of the output. The First Baptist Church in Pensacola was built of this brick.

This clay may be used for terra-cotta, stoneware, roofing tile, flower pots, as well as the common structural materials.

This is not a red-burning clay as would be anticipated from its association with limonite, but a very light-pink at cones 010 and 05 and grades into buff, gray and grayish-brown as the temperature is increased. The physical properties are as follows:

Physical Properties of Barrineau Bros. Clay, Quintette (Lab. No. o-68).

Plasticity, judged by feel	Excellent.
Water of plasticity	25.00%
Pore water	0.38%
Shrinkage water	24.62%
Linear air shrinkage	11.4 %
Volume air shrinkage	37.2 %
Modulus of rupture, average	421.0 pounds per square inch.
Slaking test	10 minutes.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.4	12.68	26.45	Cream.
1050	0.6	12.14	25.40	Cream.
1150	1.1	8.88	22.70	Buff.
1190	1.6	8.31	20.00	Buff.
1230	1.8	8.22	19.40	Buff.
1310	2.6	5.03	17.00	Gray.
1370	2.6	4.62	16.80	Gray.
1430	3.1	2.54	10.25	Gray.

Only about ten feet of this clay are exposed above the river at Dexland Bluff, six or seven miles south of Quintette. The deposit, however, probably has a much greater thickness. Its physical properties are:

Physical Properties of Dexland No. 1 (Lab. No. o-82).

Plasticity, judged by feel	Excellent.
Water of plasticity	27.95%
Pore water	1.30%
Shrinkage water	26.65%
Linear air shrinkage	10.0 %
Volume air shrinkage	30.3 %
Modulus of rupture, average	547.4 pounds per square inch.
Slaking test	24 hours.

Steel hard at cone 010.
Overfires at cone 18.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	18.43	29.20	Pink.
1050	1.5	18.75	32.20	Gray.
1150	2.5	13.80	27.80	Brown.
1190	5.0	10.45	22.20	Brown.
1230	5.0	11.07	25.10	Buff.
1310	5.0	7.66	18.70	Buff.
1370	5.0	5.74	16.55	Buff.
1430	7.5	3.88	12.30	Buff.

At Molino two brick plants are now in operation. Both of these are located on the Louisville and Nashville Railroad. The Dolores Brick Company is located about one-half mile and the Pensacola Brick Com-

pany about one mile north of Molino station. The Dolores Brick Company has been located here about twenty years, but the Pensacola Brick Company is just completing the erection of its plant and is now in readiness to market its product. The McMillan Brick Company formerly operated a plant about three miles north of Molino.

The clay exposed in this locality is eighty or more feet in thickness. Sixty feet of clay are exposed in one of the Dolores pits and borings twenty feet deep in the floor of workings did not penetrate the bottom. The clay also extends for a considerable distance northward and westward.

In each exposure at this locality the clay is cross-bedded and is interstratified with numerous sand layers. The sand layers are thin while the clay strata are thick and relatively pure. The run of bank is used at both plants and the sandy material is thoroughly mixed with the pure clay. The raw clay is brownish-gray in color, has good plasticity and working qualities and dries easily. It is a light, red-burning clay.

Both plants using this clay make face brick and common brick. Their principal markets are in west Florida and southern Alabama, Mississippi and Louisiana. Pensacola, Mobile and New Orleans are the heaviest users of the Dolores product.

This clay may be equally well used for hollow block ware, fireproofing, and drain tile. It is not suitable, however, for paving brick, sewer-pipe, or other vitrified products. It has the following physical properties:

Physical Properties of Dolores Brick Company Clay (Lab. No. 0-1).

Plasticity, judged by feel	Excellent.
Water of plasticity	22.90%
Pore water	1.05%
Shrinkage water	21.85%
Volume air shrinkage	21.05%
Linear air shrinkage	7.3 %
Modulus of rupture, average	237.4 pounds per square inch.
Slaking test	1 hour.

Steel hard at cone 15.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	17.31	34.15	Light red.
1050	0.3	17.13	33.68	Light red.
1150	0.3	16.18	33.33	Brick red.
1190	0.3	13.51	31.98	Brick red.
1230	0.7	13.36	31.00	Brick red.
1310	0.7	12.89	30.68	Brick red.
1370	0.7	12.47	29.80	Brick red.
1430	1.7	9.03	26.84	Brick red.

A common-brick plant was formerly operated at Bluff Springs in the northern end of the county. This plant used a surface, sandy clay.

FLAGLER COUNTY

Flagler County lies on the east coast between the St. Johns River valley and the ocean. Its surface exposures show chiefly sands and marls with a few thin local clays, with the exception of the western part of the county where some fairly extensive clays of good quality bordering Crescent Lake are found.

The western portion of the county is not served by a railroad, but Crescent Lake offers facilities for water transportation by its connection with the St. Johns River. Periodical freight service is maintained by at least one of the lines operating on that river.

A gray clay exposed in numerous places in the vicinity of Shell Bluff has a thickness of more than eight feet and underlies a considerable area in this section of the county. Its overburden consists of less than three feet of sand and soil. Its plasticity is excellent; it dries without difficulty and its workability is, in general, satisfactory. In most places it is underlain by marl or shell beds. The clay, however, contains numerous calcareous concretions which render fine grinding and thorough mixing necessary in order to avoid subsequent swelling of the ware due to slaking of the lime. These concretions are too small to be successfully screened out without first drying the clay.

When properly ground and mixed this clay may be used for common brick, drain tile and hollow-block ware. It is not suited, however, for the manufacture of any product where vitrification is desired as the ware has a distinctly porous, open texture at cone 15.

A sample of the clay taken from a boring near the office of the Southern Farm Land Company at Shell Bluff has the following physical properties:

Physical Properties of Shell Bluff Clay (Lab. No. o-76).

Plasticity, judged by feel	Excellent.
Water of plasticity	22.30%
Pore water	1.19%
Shrinkage water	21.11%
Linear air shrinkage	10.5 %
Volume air shrinkage	28.3 %
Modulus of rupture, average	789.9 pounds per square inch.
Slaking test	3 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	12.86	31.50	Brick red.
1050	0.5	12.20	30.50	Brick red.
1150	0.5	11.36	29.70	Brick red.
1190	0.5	11.27	29.40	Brick red.
1230	0.5	10.75	28.30	Brick red.
1310	1.0	10.15	28.20	Brick red.

FRANKLIN COUNTY

Franklin County borders the Gulf of Mexico and lies between the Apalachicola and Ocklocknee rivers. The surface exposures consist of sands and marls, but no clays of any commercial importance are known.

GADSDEN COUNTY

Gadsden County lies in the northwestern part of the State between the Apalachicola and Ocklocknee rivers and the formations exposed are the Chattahoochee, Alum Bluff, and a surface mantle of Pleistocene or Recent. The Chattahoochee, while primarily a limestone, contains some interbedded clays and residual clays also abound in this formation. The Alum Bluff consists of beds of sand, clay and fuller's earth. In addition to these clays there are some more recent flood-plain clays along the Apalachicola and Ocklocknee rivers.

Deposits of sand-clay road material are common in the county and essentially all the roads in the county are made of this material.

Very few of the Chattahoochee formation clays, either the sedimentary or the residual ones, are of any value for manufactured products. In general their working qualities are poor. Most of them are calcareous, have a high shrinkage, warp and crack badly and have poor plasticity. A sample which may be considered as illustrative of the great mass of Chattahoochee clays in the county was taken at an exposure in the roadside about two miles east of the State Hospital near Chattahoochee. This is a grayish-green jointed clay of low plasticity, containing a few flint concretions and geodes. It is worked only with difficulty. This clay is not appreciably calcareous. In a burned condition it is suited only for railroad ballast. A few of its physical properties are:

Physical Properties of State Hospital Road Clay (Lab. No. o-79).

Plasticity, judged by feel	Poor.
Water of plasticity	32.25%
Pore water	5.40%
Shrinkage water	29.85%
Linear air shrinkage	17.50%
Volume air shrinkage	45.75%
Steel hard at cone 010.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Volume Shr. Per Cent.*	*Color.*
950°C.	2.5	6.7	Brick red.
1050	2.5	7.6	Brick red.

One of the Chattahoochee limestone residual clays, which is an exception to the average condition found in the county, occurs in the northeast edge of River Junction where a plant manufacturing common brick was operated in 1907 by Mr. Ed Royston. The product of this plant has been used in the construction of several buildings in River Junction and Chattahoochee. This deposit is located only a few rods from the Atlantic Coast Line and Seaboard Air Line Railway tracks. Four railroads, the Atlantic Coast Line, the Seaboard Air Line, the Louisville and Nashville, and the Apalachicola Northern, meet at River Junction, thus affording shipping facilities to points in west Florida and southern Georgia and Alabama.

The Royston deposit is irregular in thickness but is as much as fifteen feet in places and underlies a fairly extensive area in a small valley at River Junction.

This is a red-burning clay of medium shrinkage and good drying qualities and working. It may be used for ordinary structural materials such as common brick, hollow-block ware, drain tile, etc.

It has the following physical properties:

Physical Properties of Royston Clay, River Junction (Lab. No. o-71).

Plasticity, judged by feel	Excellent.
Water of plasticity	28.45%
Pore water	1.66%
Shrinkage water	26.79%
Linear air shrinkage	11.7 %
Volume air shrinkage	29.4 %
Modulus of rupture, average	451.8 pounds per square inch.
Slaking test	2 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	11.02	29.10	Brick red.
1050	0.3	11.50	28.20	Brick red.
1150	0.8	11.11	27.10	Gray.
1190	1.3	10.22	26.80	Gray.
1230	1.8	9.73	25.10	Gray.
1310	2.8	9.60	24.75	Gray.

The Alum Bluff clays were formerly worked in a number of places in Gadsden County. One plant was operated at Hinson about sixty-five years ago. Plants have also been located near Mount Pleasant, Gretna, Quincy, and Chattahoochee.

The plant at Quincy worked one of the clays overlying the fuller's earth. This clay is now removed as overburden in mining the fuller's earth and could therefore be used as a by-product. It has medium shrinkage, good working qualities and is suitable for common brick, hollow blocks and drain tile. A vitrified product cannot satisfactorily be made from it, however, as it still has a porous, open texture at cone 15. It has the following physical properties:

Physical Properties of Floridin Overburden Clay, Quincy (Lab. No. o-38).

Plasticity, judged by feel............	Excellent.
Water of plasticity.................	25.65%
Pore water	0.50%
Shrinkage water	25.15%
Linear air shrinkage................	12.20
Volume air shrinkage...............	36.82%
Modulus of rupture, average........	315.7 pounds per square inch.
Slaking test	2 minutes.
Steel hard at cone 5.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.2	11.40	27.85	Brick red.
1050	1.7	11.10	27.20	
1150	1.8	11.10	27.20	
1190	2.2	10.50	27.10	
1230	2.8	10.50	27.10	
1310	3.7	8.33		

Underlying the northeast part of the town of Chattahoochee and also forming the surface materials at the headquarters of the State Hospital is a deep red, very sandy clay. It is valueless for fired products, but is suitable for sand-clay road metal. As an illustration of this type of clay the following physical properties are given:

Physical Properties of State Hospital Red Sandy Clay (Lab. No. 0-37).

Plasticity, judged by feel	Fair.
Water of plasticity	21.40%
Pore water	0.10%
Shrinkage water	21.30%
Linear air shrinkage	6.40%
Volume air shrinkage	17.90%
Modulus of rupture, average	84.5 pounds per square inch.
Slaking test	36 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.6	22.37	36.70	Brick red.
1050	0.6	18.40	36.50	
1150	1.4	17.45	36.50	

A surface clay exposed on the A. J. Key Plantation, about three miles southeast of Quincy on the Seaboard Air Line Railway, contained numerous limonitic concretions. The plasticity and drying qualities are good, but the transverse strength is very low. This clay is of no practical value for the manufacture of burned products. Its physical properties are:

Physical Properties of Key Plantation Clay (Lab. No. 0-41).

Plasticity, judged by feel	Excellent.
Water of plasticity	24.75%
Pore water	0.27%
Shrinkage water	24.48%
Linear air shrinkage	5.70%
Volume air shrinkage	15.75%
Modulus of rupture, average	92.5 pounds per square inch.
Slaking test	24 hours.
Overfires at cone 5.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	26.60	45.80	Brick red.
1050	0.8	24.48	43.10	Brick red.
1150	2.3	23.55	43.60	Brick red.
1190	3.3	16.70	37.10	Brick red.

By far the best clays in the county for burned products are the flood-plain clays along the Apalachicola and Ocklocknee rivers. One such deposit is located on the State Hospital Farm, about one mile northwest of Chattahoochee, in a field joining the Apalachicola River and the Georgia-Florida boundary. The thickness of this deposit is not definitely known, but it is more than five or six feet. It is known to underlie an area of sixty or eighty acres in Georgia and Florida.

This clay may be used to make an excellent grade of common building brick and similar structural materials. Rail transportation is not nearer than about three miles, but the Apalachicola River offers water transportation to points down that river and up the Flint and Chattahoochee Rivers in Georgia and Alabama. This clay has the following physical properties:

Physical Properties of State Hospital River Field (Lab. No. o-8).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.50%
Pore water	0.94%
Shrinkage water	25.56%
Linear air shrinkage	8.1 %
Volume air shrinkage	23.6 %
Modulus of rupture, average	301.1 pounds per square inch.
Slaking test	36 hours.
Steel hard at cone 9.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.9	17.95	39.02	Brick red.
1050	1.1	20.50	39.40	Brick red.
1150	1.9	16.45	39.40	Brick red.
1190	4.4	13.15	38.50	Brick red.
1230	4.9	12.70	31.20	Brick red.
1310	4.9	8.35	31.60	Brick red.
1370	5.4	3.29	25.50	Brick red.
1430	7.9		14.90	Brick red.

The Ocklocknee Brick Company, located on the Seaboard Air Line Railway at Lawrence, uses a flood-plain clay. The deposit is five feet thick and is overlain by six inches of soil. The clay has good plasticity and bonding strength and presents no drying difficulties. It is now used in the manufacture of common brick. An excellent grade of common brick, hollow-block ware, and drain tile may be made from it. A series of compression tests made on the Ocklocknee Brick Company's product by the Birmingham branch of the Pittsburgh Testing Laboratory were as follows:

Compression Tests on Ocklocknee Brick.

HARD BRICK.

Weight pounds.	*Dimensions.*	*Area, square inches.*	*Load, pounds.*	*Unit load, pounds per square inch.*
No. 1—4.1	3.6x7.8	28.08	78,900	2,810
No. 2—4.1	3.7x7.7	28.49	83,600	2,935
No. 3—4.2	3.7x7.8	28.86	88,500	3,067
Average				2,937

MEDIUM BRICK.

	Weight pounds.	*Dimensions.*	*Area, square inches.*	*Load pounds.*	*Unit load, pounds per square inch*
No. 1	4.3	3.7x7.6	28.12	73,560	2,617
No. 2	4.3	3.6x7.7	27.72	73,190	2,640
No. 3	4.2	3.6x7.6	27.36	75,140	2,746
Average					2,668

SOFT BRICK.

	Weight pounds.	*Dimensions.*	*Area, square inches.*	*Load pounds.*	*Unit load, pounds per square inch*
No. 1	4.1	3.7x7.8	28.86	106,200 plus	3,680 plus
No. 2	4.0	3.7x7.7	28.49	99,890	3,506
No. 3	4.0	3.6x7.6	27.36	106,200 plus	3,882 plus
Average					3,689 plus

The Ocklocknee clay has the following physical properties:

Physical Properties of the Ocklocknee Clay (Lab. No. o-30).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.00%
Pore water	0.52%
Shrinkage water	25.48%
Linear air shrinkage	12.2 %
Volume air shrinkage	33.2 %
Modulus of rupture, average	988.0 pounds per square inch.
Slaking test	2 days.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	13.10	28.40	Reddish brown.
1050	0.7	14.22	29.00	Reddish brown.
1150	0.8	10.50	25.50	Reddish brown.
1190	0.3	9.75	24.00	Reddish brown.
1230	0.3	9.60	23.20	Reddish brown.
1310	3.8	9.05	22.75	Reddish brown.
1370	4.3	9.55	20.30	Reddish brown.
1430	4.8	8.42	18.75	Reddish brown.

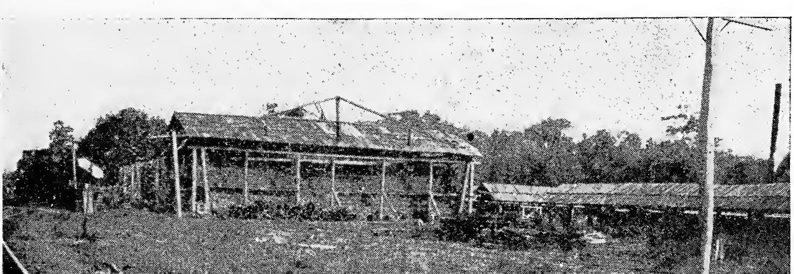

FIG. 23.—General View, Ocklocknee Brick Co., Lawrence, Gadsden County.

The Tallahassee Pressed Brick Company, Havana, located farther up the Ocklocknee River, also utilizes a flood-plain clay having properties very similar to the clay previously described. This plant is located on the Georgia, Florida and Alabama Railroad. The deposit is about five feet thick, overlain by about six inches of soil, and has been proven on about sixty acres. It probably underlies a more extensive area.

This clay has excellent working qualities. A good grade of common building brick, fireproofing, hollow blocks, or drain tile may be made from it. Its physical properties are:

Physical Properties of the Tallahassee Pressed Brick Company Clay (Lab. No. 0-17).

Plasticity, judged by feel	Excellent.
Water of plasticity	25.65%
Linear air shrinkage	10.3 %
Volume air shrinkage	27.8 %
Modulus of rupture, average	498.4 pounds per square inch.
Slaking test	48 hours.
Steel hard at cone 010.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	17.32	33.00	Brick red.
1050	0.3	16.80	32.45	Brick Red.
1150	0.7	14.20	30.25	Brick Red.
1190	0.7	11.42	25.50	Brick Red.
1230	1.2	11.05	29.20	Brick Red.
1310	1.8	10.90	23.75	Brick red.
1370	2.2	10.18	20.20	Brown.
1430	2.2	9.30	14.20	Brown.

The two plants located on the Ocklocknee River supply a demand for brick throughout northwestern Florida and southern Georgia.

GLADES COUNTY

Glades County borders Lake Okeechobee on the west and is underlain chiefly by sands and marls in which exposures are rare. No clays of importance are known.

HAMILTON COUNTY

Hamilton County is located in north Florida between the Suwannee and Withlacoochee rivers. The surface materials are chiefly Chattahoochee, Alum Bluff and Recent formations, in which surface, sandy clays, in places containing some gravel, are common.

At the bridge across the Suwannee River at White Springs an eight-foot bed of a green-colored, plastic, jointed clay, overlain by six feet of soil, is exposed. This clay has a high air shrinkage and warps and cracks badly in drying and burning. It therefore is of no value in the manufacture of burned clay products.

An exposure of a soft, white shale or partially consolidated clay occurs on the west bank of the Suwannee River about five miles north-east of White Springs. Only one exposure of this clay was seen in this vicinity, but it probably underlies a considerable area on both sides of the river. The deposit is overlain by a sand ranging from six to ten feet in thickness. A twenty-two-foot thickness of clay is exposed above the river level. Its depth below the river is not known.

This clay has excellent plasticity and working qualities and dries without difficulty. Its high air and fire shrinkage are detrimental and this, in connection with a slight tendency to warp in firing, renders it useless for burned products. The clay vitrifies at cone 3 and becomes distinctly porous at cone 5. Its physical properties are:

Physical Properties of White Springs White Shale (Lab. No. 0-3).

Plasticity, judged by feel	Excellent.
Water of plasticity	52.50%
Pore water	12.80%
Shrinkage water	39.70%
Linear air shrinkage	14.3 %
Volume air shrinkage	42.8 %
Modulus of rupture, average	470.8 pounds per square inch.
Slaking test	24 hours.
Steel hard at cone 010.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	8.2	32.20	52.63	Cream.
1050	5.7	30.51	46.02	Cream.
1150	15.7	17.02	31.82	Light yellow.
1190	16.7	1.33	5.72	Light yellow.
1230	14.7	0.78	2.97	Light yellow.

HARDEE COUNTY

Hardee County is situated in south Florida and is underlain by the Bone Valley and Caloosahatchee formations. The Bartow Clay is found extensively throughout the central and western parts of the county. (For discussion on the Bartow Clay see Polk County, page 195.) A coarse, reddish to brownish, sandy clay is exposed near Bowling Green, Zolfo

and Wauchula. This material is desirable for sand-clay road metal. No clays suited for burned products are known in the county.

HERNANDO COUNTY

Hernando County is situated on the Gulf coast in west-central Florida and is underlain by the Ocala and Tampa formations. The Tampa formation occupies the southeastern part of the county and several outliers scattered northward throughout the region of the Ocala formation. Brooksville, the county seat, is located in the center of one of these outliers, having a radius of about six miles.

Residual clays are of common occurrence in both the Ocala and Tampa limestones, but sedimentary clays occur only in the Tampa formation.

The Ocala residual clays are usually sandy, contain numerous flint concretions and the deposits are very irregular in thickness and extent. Pockets of such clay are frequently encountered in mining the hard-rock phosphate which occurs extensively in this region. These clay pockets are of insufficient size to warrant the separation of the clay from the other materials.

The Tampa formation clays are worked at Brooksville and are found at numerous other localities in that vicinity. Few of them are desirable for burned products as their working qualities are rather poor. They are subject to excessive cracking during drying and burning which would result in severe losses during the process of manufacture. The transverse strength is relatively low in all of them.

The Morris and Blumer Brick Company, located about one mile south of Brooksville, works one of these Tampa formation residual clays. The deposit consists of two parts, an upper two feet, which is dark-brown in color and somewhat sandy, and a lower member, which is very light in color and averages about eight feet in thickness. The deposit is underlain by the Tampa limestone and is separated from it by an irregular contact. Flint and limestone concretions occur in the clay. The contact between the two members of this deposit is fairly distinct and probably represents a former water table. This deposit underlies an extensive area south and west of Brooksville.

At this plant the dark upper clay and the lower white one are mixed in equal proportions. The sand in the upper clay somewhat reduces the shrinkage of the mixture. These clays can be dried only with difficulty.

The green brick are stacked in air-drying sheds where they are protected from wind and direct sunlight. They are first covered with wet burlap and the ground underneath the racks is flooded with water to prevent rapid drying. Eight weeks are required to dry the ware in this manner without heavy losses from cracking. Careful firing with very gradual increases in temperature are also necessary to avoid further cracking. A common building-brick is made at this plant.

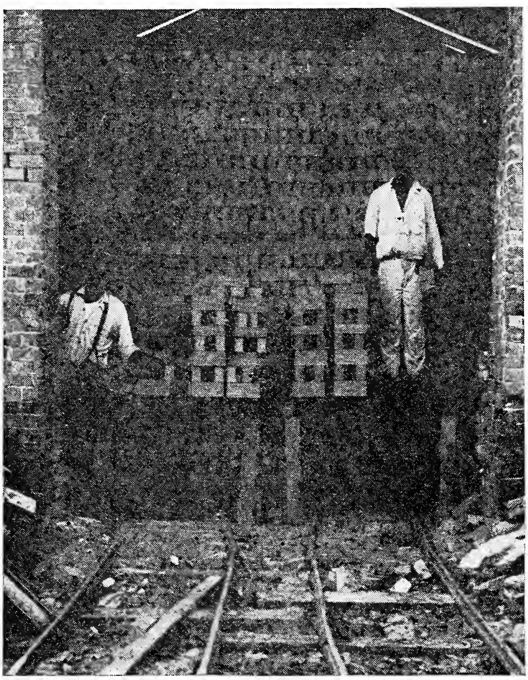

FIG. 24.—Setting a kiln. Morris and Blumer Brick Company, Brooksville, Hernando County.

The plant is located on the Tampa Northern Railroad, which renders Tampa and St. Petersburg and surrounding points available as a market.

The upper dark, sandy clay has the following physical properties:

Physical Properties of Morris and Blumer Brick Company Upper Sandy Clay (Lab. No. 0-23).

Plasticity, judged by feel	Excellent.
Water of plasticity	24.95%
Pore water	0.57%
Shrinkage water	24.38%
Linear air shrinkage	12.7 %
Volume air shrinkage	31.1 %
Modulus of rupture, average	345.4 pounds per square inch.
Slaking test	5 minutes.

Overfires at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.7	11.82	23.95	Buff.
1050	0.3	12.38	26.75	Buff.
1150	0.3	11.68	26.45	Buff.
1190	0.3	11.40	25.50	Buff.
1230	0.5	11.40	26.45	Buff.
1310	2.3	11.80	27.75	Buff.

The lower light-colored clay has the following physical properties:

Physical Properties of Morris and Blumer Brick Company Lower White Clay (Lab. No. 0-24).

Plasticity, judged by feel	Excellent.
Water of plasticity	36.40%
Pore water	0.88%
Shrinkage water	35.52%
Linear air shrinkage	8.90%
Volume air shrinkage	22.05%
Modulus of rupture, average	114.0 pounds per square inch.
Slaking test	3 minutes.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	11.4	4.58	12.15	Salmon.
1050	13.6.	4.50	10.45	Gray.
1150	13.6			Gray.
1190	13.1	3.53	8.95	Gray.
1290	13.1	2.58	6.65	Gray.
1310	12.1			
1370	16.1			

A similar clay is exposed a few rods south of the Tampa Northern station. It may likewise be used for a common brick, but it also requires very careful drying and burning to avoid excessive cracking. Its physical properties are:

Physical Properties of Brooksville Tampa Northern Clay (Lab. No. 0-21).

Plasticity, judged by feel	Excellent.
Water of plasticity	34.50%
Linear air shrinkage	15.2 %
Volume air shrinkage	41.2 %
Modulus of rupture, average	147.0 pounds per square inch.
Slaking test	3 minutes.

Steel hard at cone 010.
Overfires at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.0	7.60	18.50	Salmon.
1050	2.8	7.08	18.30	Brown.
1150	3.8	6.88	16.20	Gray.
1190	5.8	6.42	15.70	Gray.
1230	3.8	5.82	10.10	Gray.

A clay is exposed in the northeastern edge of Brooksville and vicinity which is unfitted for any kind of burned product. Its plasticity is very poor and its shrinkage is high. This clay warps badly, but is comparatively free from cracking. Its physical properties, which are given for the purpose of illustration, are:

Physical Properties of Brooksville Clay (Lab. No. 0-56).

Plasticity, judged by feel	Poor.
Water of plasticity	38.45%
Pore water	4.90%
Shrinkage water	33.55%
Linear air shrinkage	18.8 %
Volume air shrinkage	35.8 %
Modulus of rupture, average	218.0 pounds per square inch.
Slaking test	5 minutes.

Steel hard at cone 010.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	3.2	6.46	17.20	Salmon.
1050	4.2	6.02	16.30	Salmon.
1150	6.7	6.61	16.60	Gray.
1190	7.0	5.49	13.40	Gray.

A brownish-gray, slightly sandy clay occurs in the Annuttalaga Hammock about one-half mile north of Brooksville and extends northward for about two miles. The thickness of the deposits is not known, but is as much as eight feet in places. The clay is suitable for a soft, porous common building brick of only fair quality. Its physical properties are:

Physical Properties of Brooksville Hammock Clay (Lab. No. 0-59).

Plasticity, judged by feel..........	Excellent.
Water of plasticity.................	27.40%
Pore water	1.49%
Shrinkage water	25.93%
Linear air shrinkage................	12.1 %
Volume air shrinkage................	28.8 %
Modulus of rupture, average........	215.3 pounds per square inch.
Slaking test	3 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.47	16.16	34.80	Brick red.
1050	0.4	16.64	34.40	Brick red.
1150	1.6	15.80	33.50	Brick red.
1190	2.4	16.00	27.75	Brick red.
1230	2.9	15.49	23.75	Brick red.

HIGHLANDS COUNTY

Highlands County lies in the south-central part of the peninsula just northwest of Lake Okeechobee. The Alum Bluff formation underlies the central part of the county from Lake Childs northwestward and contains abundant coarse, red, sandy clay very suitable for sand-clay road material. The remainder of the county is underlain by sand and marls. No clays suitable for burned products are known.

HILLSBOROUGH COUNTY

Hillsborough County lies on the western side of the peninsula at the head of Tampa Bay. It is underlain by the Tampa, Alum Bluff and Bone Valley formations. The Bone Valley Gravel carries the Bartow clay which is found in numerous localities from Plant City southward to the Manatee River. (For a description of the Bartow Clay see Polk County, page 195.)

The Alum Bluff formation contains some phosphatic and sandy clays, but none having any usefulness for burned products.

The Tampa formation consists of two distinct strata of light-green plastic clays separated by a limestone. The upper clay is exposed in numerous localities, while the lower one has very few, if any, natural exposures and is found chiefly in excavations and wells. Residual clays from the Tampa limestone are of common occurrence.

The upper Tampa clay is exposed in several places along the Hillsborough River and has formerly been worked at Tampa. Both the Tampa Northern Railroad and the Atlantic Coast Line Railroad cross exposures of this clay.

The Tampa Brick Company's plant, now abandoned, was located about five miles northeast of the city on the Hillsborough River. The deposit consists of about ten feet of a light-green plastic clay containing numerous cherty concretions. A two-foot overburden of loose surface sand and soil overlies the clay.

This is a grayish, buff-burning clay which is still distinctly porous at cone 15, hence is not suited for any product where vitrification is essential. It may, however, be used for common building-brick and hollow-block ware. Its physical properties are:

Physical Properties of Tampa Brick Company Clay (Lab. No. o-34).

Plasticity, judged by feel............	Excellent.
Water of plasticity..................	32.45%
Pore water	1.05%
Shrinkage water	31.40%
Linear air shrinkage................	12.80%
Volume air shrinkage...............	35.85%
Modulus of rupture, average........	598.2 pounds per square inch.
Slaking test	5 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	16.75	31.50	Buff.
1050	0.3	16.20	31.10	Buff.
1150	0.2	14.18	29.75	Buff.
1190	2.2	14.20	27.80	Buff.
1230	2.2	13.25	27.70	Buff.
1310		13.20	26.60	Buff.

The Temple Terrace Tract, located about six miles northeast of Tampa on the Hillsborough River, is underlain by a yellowish and reddish, sandy clay which is suited only for sand-clay road material. The southern edge of the tract is underlain by the Tampa formation clay which has the same properties as the Tampa Brick Company clay described in the foregoing paragraph.

The property of Dr. W. P. Chamberlain, two miles north of Sulphur Springs, is underlain by several thin variable clay strata interbedded with sand. The clay is of insufficient quantity and at too great depth to

be of any commercial value. One boring about one-quarter mile northwest of the house indicated the following section:

Section of Strata on the Dr. W. P. Chamberlain Property, near Sulphur Springs.

	Feet.	Inches.
Sand, gray	2	—
Sand, white	12	2
Clay, gray, very plastic	—	2
Sand, white	2	—
Clay, red, plastic	—	2
Sand, white	?	—

Another boring only about ten rods to the northeast of the foregoing one showed the gray, plastic clay to have a thickness of one and one-half feet.

Pockets of a buff, plastic clay, residual from the Tampa limestone, are of common occurrence in the western edge of Tampa and beyond the city limits. These are exceedingly irregular in thickness and extent and are of insufficient size to warrant exploitation.

HOLMES COUNTY

Holmes County lies in northwest Florida adjoining the Florida-Alabama boundary and is underlain by the Ocala, Chattahoochee and Alum Bluff formations. Sandy surface clays are of common occurrence but none are known that are desirable for burned products.

JACKSON COUNTY

Jackson County lies in west Florida just west of the Apalachicola River. It is underlain by the Ocala, Marianna, Chattahoochee, Alum Bluff, and Pleistocene formations. Residual Ocala, Marianna and Chattahoochee clays are found, but few are of commercial importance. The Alum Bluff formation consists essentially of sands and marls. Some Pleistocene flood-plain clays occur along the Apalachicola River.

A deposit of clay, probably Pleistocene, occurs on the property of the Florida Industrial School for Boys, three miles southwest of Marianna, and is now being worked for common brick. This is a red and gray clay from eight to twelve feet thick overlain by a brown, sandy clay from one to two feet in thickness.

Marianna is the nearest shipping point, but most of the output from this plant is used on the farm and the remainder is sold locally.

The plant is small and has only one kiln which has a 110,000 capacity. All the work is done by boys ranging in age from eight to eighteen years.

The clay has excellent plasticity. Its linear fire shrinkage increases from 3.1 per cent at cone 010 to 10.6 per cent at cone 5. Its porosity and absorption percentages are low at cone 1 and remain so until after cone 9 is passed. This clay should be used only for common structural materials as common and face brick, fireproofing, hollow-block ware, drain tile and similar products and should be burned at about cone 010. Its physical properties are:

Physical Properties of Florida Industrial School Clay (Lab. No. o-28).

Plasticity, judged by feel	Excellent.
Water of plasticity	36.65%
Pore water	0.46%
Shrinkage water	36.19%
Linear air shrinkage	14.40%
Volume air shrinkage	38.10%
Modulus of rupture, average	421.2 pounds per square inch.
Slaking test	5 minutes.

Steel hard at cone 010.
Overfires at cone 12.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	3.1	11.95	26.00	Brick red.
1050	10.6	8.05	20.75	Brick red.
1150	10.6	2.10	8.60	Brick red.
1190	12.6	1.70	7.50	Brick red.
1230	12.6	1.67	5.80	Brick red.
1310	13.6	1.50	6.10	Brick red.

JEFFERSON COUNTY

Jefferson County lies in north Florida and extends from the northern boundary of the State to the Gulf of Mexico. It is underlain by the Alum Bluff formation in the northern part of the county and the Chattahoochee formation in the southern part. A heavy mantle of red, coarse, sandy clay covers most of the county.

Several brick plants have formerly been operated in the county. Three of these, located near Monticello, have worked a sandy, jointed, surface clay. Another small plant worked a red surface clay on the Bishop Homestead, four miles south of Aucilla. Clays from each of these localities may be used for common brick. The Bishop clay is too far from transportation to be of commercial importance.

In a series of tests made by the United States Bureau of Standards in 1914 a clay from near Thomas City was included. Its qualities indicate that it may be used for a common building-brick. Its physical properties are:[1]

Physical Properties of Thomas City Clay (Bureau of Standards Sample No. 21).

Plasticity	Good.
Water of plasticity	28.9%
Linear air shrinkage	6.0%

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.22	35.6	Buff.
1020		34.0	Buff.
1050		32.2	Buff.
1080		33.4	Buff.
1110	1.09	33.8	Buff.
1140		33.6	Buff.
1170		33.6	Buff.
1200		33.7	Buff.
1230	0.55	32.8	Buff.
1260		34.4	Buff.
1290		33.7	Buff.
1320	0.49	33.5	Buff.

LAFAYETTE COUNTY

Lafayette County lies in the northwestern part of the peninsula and is underlaid by the Ocala and Chattahoochee formations. Both of these contain clays to some extent but none that may be considered of commercial importance.

LAKE COUNTY

Lake County lies in the central part of the peninsula in the heart of the Lake Region. Its surface formations are essentially all sand-clays in which there is a high percentage of coarse, sharp, angular sand and some gravel with a good, reddish, clay bond. This material is very desirable for sand-clay road material, but is not adapted to other uses.

Extensive deposits of sedimentary kaolins also occur in Lake County and are discussed in detail in a subsequent chapter. (Chapter IX.)

Numerous lacustrine deposits also occur in Lake County. These are usually of limited areal extent and relatively thin.

One of these occurs on the property of B. H. Nuckolls near Umatilla (Sec. 1, Twp. 18 S., R. 26 E.). This is a blue clay with a bright-red mot-

[1]Sellards, E. H., Report of Clay Tests for Paving Brick, Florida Geological Survey Press Bulletin No. 7, 1915.

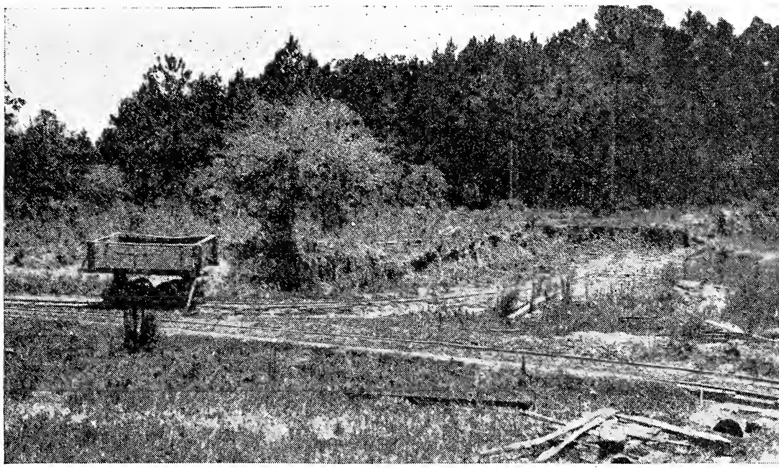

FIG. 25.—Clay pit, Keystone Brick Co., Whitney, Lake County.

FIG. 26.—View showing kiln sealed ready for firing. Keystone Brick Co., Whitney, Lake County.

tling, having excellent plasticity but a high air shrinkage. It occurs in a bed two and one-half feet thick overlain by six feet of sand. The overburden is too heavy for a clay of that thickness to be of commercial importance.

The Keystone Brick Company at Whitney works a lacustrine deposit ranging from seven to twelve feet in thickness and overlain by about eighteen inches of sand. The clay is also underlain by sand. Two pits about sixty yards apart have been opened. The clay in one of these is a little more sandy than in the other.

A good grade of common brick is made which is shipped to markets throughout peninsular Florida. Tampa and St. Petersburg use the greater part of the output. This plant is located on a branch of the Seaboard Air Line Railway. The Keystone brick, while not particularly a semi-refractory product, is widely used in South Florida for fire-box lining under boilers.

This clay retains a soft, porous texture at cone 15 and may be used only for common building-brick. Its physical properties are:

Physical Properties of Keystone Brick Company Clay (Lab. No. 0-54).

Plasticity, judged by feel	Excellent.
Water of plasticity	23.90%
Pore water	1.58%
Shrinkage water	22.40%
Linear air shrinkage	10.9 %
Volume air shrinkage	32.3 %
Modulus of rupture, average	491.3 pounds per square inch.
Slaking test	5 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.6	19.84	33.40	Brick red.
1050	1.1	11.49	30.20	Brick red.
1150	1.1	9.43	26.90	Brick red.
1190	1.6	9.78	26.50	Brick red.
1230	2.1	9.69	24.20	Brick red.
1310	2.6	8.40	23.50	Brick red.

Another brick plant was formerly operated near Whitney by the Whitney Brick Company. The deposit was a sandy lacustrine clay, from which a red common brick was made.

LEE COUNTY

Lee County lies between Lake Okeechobee and the Gulf of Mexico and is underlain by sands, marls and limestones of Pleistocene age. No clays of importance are known.

LEON COUNTY

Leon County is located in north Florida east of the Ocklocknee River. The Chattahoochee, Alum Bluff, Choctawhatchee and Pleistocene formations are exposed at the surface. A surface mantle of a jointed sandy clay, probably Pleistocene, covers the entire county. Flood-plain clays occur at some points along the Ocklocknee River and lacustrine clays are also found in several places.

Many years ago, before there were railroads to bring better material from other localities, bricks were made from sandy red clay just north of Tallahassee, and the remains of the yards can still be seen.

The surface mantle clays occupying the northwestern half of the county and roughly co-extensive with the Alum Bluff formation contain much coarse sand and some gravel. This material is well suited for sand-clay road material.

The surface material in the southeastern part of the county and essentially co-extensive with the Chattahoochee formation contains a high percentage of clay.

An exposure of this clay occurs in a road-clay pit about six miles south of Tallahassee on the Woodville road and just north of the Wakulla Hammock. The thickness of this deposit is not known, but more than five feet are exposed. It is overlain by about eighteen inches of surface sand and soil. This clay may be used for a fair grade of common brick, but as it retains a porous texture even at cone 16, it cannot be used for a vitrified product. It has the following physical properties:

Physical Properties of the Woodville Road Clay (Lab. No. o-5).

Plasticity, judged by feel	Fair.
Water of plasticity	31.40%
Pore water	1.33%
Shrinkage water	30.07%
Linear air shrinkage	11.3 %
Volume air shrinkage	29.8 %
Modulus of rupture, average	225.6 pounds per square inch.
Slaking test	24 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.2	17.30	35.00	Buff.
1050	1.7	18.20	35.00	Buff.
1150	4.7	14.00	27.80	Buff.
1190	5.7	13.20	27.80	Buff.
1230	6.2	11.40	25.90	Gray.
1310	6.7	10.00	19.30	Gray.
1370	6.7	9.20	19.90	Gray.
1430	7.7	8.50	18.60	Gray.

A clay exposed in several cuts along the St. Augustine Road in the region about Chaires and Capitola underlies an extensive area in this vicinity, but is not suited for the manufacture of burned products. A sample taken from a pit one-half mile west of Capitola, between the Seaboard Air Line Railway and the highway, has the following physical properties, which are given as illustrative of the clays of this general region:

Physical Properties of the Capitola Clay (Lab. No. 0-16).

Plasticity, judged by feel..........	Fair.
Water of plasticity................	28.90%
Linear air shrinkage...............	7.4 %
Volume air shrinkage..............	18.6 %
Modulus of rupture, average........	128.3 pounds per square inch.
Slaking test	2 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.1	18.30	36.20	Brick red.
1050	0.9	18.90	36.60	Brick red.
1150	1.4	18.58	36.10	Brick red.
1190	1.4	17.65	34.50	Brick red.
1230	1.9	15.30	32.50	Brick red.

A lacustrine deposit occurs on the property of C. W. Burney, one-half mile south of Miccosukee adjoining the Atlantic Coast Line Railroad. It is grayish-brown in color, contains some sand and is overlain by about three feet of soil. The clay is more than five feet in thickness and underlies approximately ten acres. This clay burns to a light pinkish-white at cones 010 and 05. It may be used for a fair grade of common brick, but on account of a highly-porous texture which it retains at cone 16 a vitrified product would be impracticable. It has the following physical properties:

Physical Properties of C. W. Burney Clay, Miccosukee (Lab. No. 0-10).

Plasticity, judged by feel..........	Excellent.
Water of plasticity................	23.50%
Pore water	0.64%
Shrinkage water	22.86%
Linear air shrinkage..............	7.6 %
Volume air shrinkage.............	20.8 %
Modulus of rupture, average........	129.2 pounds per square inch.
Slaking test	24 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.4	23.62	38.70	Pink.
1050	1.4	21.00	38.60	Pink.
1150	1.4	19.00	36.20	Brown.
1190	1.4	15.95	33.75	Pink.
1230	2.4	14.60	30.75	Gray.
1910	2.4	14.20	28.60	Gray.

Ries[1] reports a white calcareous clay outcropping on the property of W. B. Stoutamire, eighteen miles southwest of Tallahassee, Sec. 1, T. 1 S., R. 4 W., and a brick-clay on the property of J. D. Stoutamire in Sec. 15, T. 1 S., R. 4 W. This last clay, according to the same investigator, has good plasticity, 40 per cent of water of plasticity, 17 per cent air-shrinkage, 5 per cent fire-shrinkage at cone 05, and a tensile strength ranging from 175 to 210 pounds per square inch. Incipient fusion begins at cone 05 and the clay burns to a hard, dense product at cone 2. Its color is a very light buff.

Ries[2] reports a calcareous clay also on the property of W. W. Williams, about one-half mile southeast of Jackson Bluff, on the Ocklocknee River, in Sec. 21, T. 1 S., R. 4 W. The clay outcrops in the bed and along the sides of a small creek. The material is overlain by about five feet of sandy alluvium, and two and one-half feet thickness of clay is exposed. This clay has 45 per cent water of plasticity, 16 per cent air-shrinkage, tensile strength ranging from 300 to 388 pounds per square inch with an average of 338, 5 per cent fire-shrinkage at cone 01 and 12 per cent at cone 5. Vitrification seemed to occur at about cone 6 and viscosity at cone 8.

None of these clays can be used alone in the manufacture of clay products. The air-shrinkage of the J. D. Stoutamire clay and the Williams clay is too high, but if sand or other clays are added to reduce shrinkage a light-colored face brick may be made.

A bluish-black, very plastic clay is exposed in Double Creek in the southwest corner of Sec. 8, T. 1 S., R. 3 W., on the property of Hugh Black. The clay is three feet in thickness, is overlain by soil and sand ranging from six to twenty feet, and overlies a marl. This clay likewise has a high air-shrinkage.

None of the clays of this Jackson Bluff region may be considered as of commercial importance at the present time as no transportation is nearer than about eighteen miles.

The chemical analyses of the Stoutamire and Williams clays are given below:

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[1]Ries, H., Clays of United States East of Mississippi River, U. S. Geological Survey Prof. Paper No. 11, p. 83, 1903.
[2]Loc. Cit.

Chemical Analysis of W. B. Stoutamire Clay, H. Ries, Analyst[1].

Silica (SiO_2)	35.95
Alumina (Al_2O_3)	13.23
Ferric Oxide (Fe_2O_3)	1.27
Lime (CaO)	15.00
Magnesia (MgO)	5.40
Water (H_2O)	10.55
Carbon Dioxide (CO_2)	18.50
Total	99.80

Chemical Analysis of W. W. Williams Clay, H. Ries, Analyst[2].

Silica (SiO_2)	30.83
Alumnia (Al_2O_3)	15.40
Ferric Oxide (Fe_2O_3)	1.40
Lime (CaO)	13.78
Magnesia (MgO)	7.50
Water (H_2O)	7.16
Carbon Dioxide (CO_2)	20.14
Total	96.21

LEVY COUNTY

Levy County borders the Gulf of Mexico in the northern part of the peninsula and is chiefly underlain by the Ocala formation, on which are a few outliers of the Alum Bluff and Alachua formations. Numerous lacustrine deposits, usually formed in sinks, are locally present.

Residual clays from the Ocala limestone are common in the northern and eastern parts of the county. Some of these residual deposits are quite extensive in area and of fairly uniform thickness.

One such deposit is found at Williston where the clay is somewhat sandy, is red-burning, and has excellent working qualities. It may be used for common structural materials, but a vitrified product cannot be produced as its porosity remains high at the higher temperatures. A sample taken in the street in front of the Williston School building has the following physical properties:

Physical Properties of Williston School Clay (Lab. No. o-9).

Plasticity, judged by feel	Excellent.
Water of plasticity	31.20%
Pore water	1.69%
Shrinkage water	29.51%
Linear air shrinkage	12.60%
Volume air shrinkage	35.75%
Modulus of rupture, average	232.1 pounds per square inch.
Slaking test	2 minutes.

[1]U. S. Geol. Survey Prof. Paper No. 11, p. 82, 1903.
[2]U. S. Geol. Survey Prof. Paper No. 11, p. 82, 1903.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	2.4	18.10	32.50	Red.
1050	2.4	18.00	32.20	Red.
1150	4.9	14.75	31.90	Red.
1190	5.4	14.80	30.50	Red.
1230	5.9	13.10	28.20	Red.
1310	6.4	12.80	23.20	Red.

While many of these residual clays are adapted to the manufacture of burned products, it is to be noted that a great many others are not. The light-yellow or buff raw clays quite free from sand, found in many places in this region, are, as a rule, unfitted for burned products.

A white, plastic clay, free from sand, is encountered at a depth of thirty-nine feet on the property of J. H. Link, at Bronson. A white, plastic clay also underlies portions of the region about Chiefland at a depth of twenty or more feet. Samples adequate for testing were not available.

A yellowish-white calcareous clay is found underlying portions of Inglis, but its lime content is too high for use in burned products.

LIBERTY COUNTY

Liberty County lies in middle Florida between the Ocklocknee and

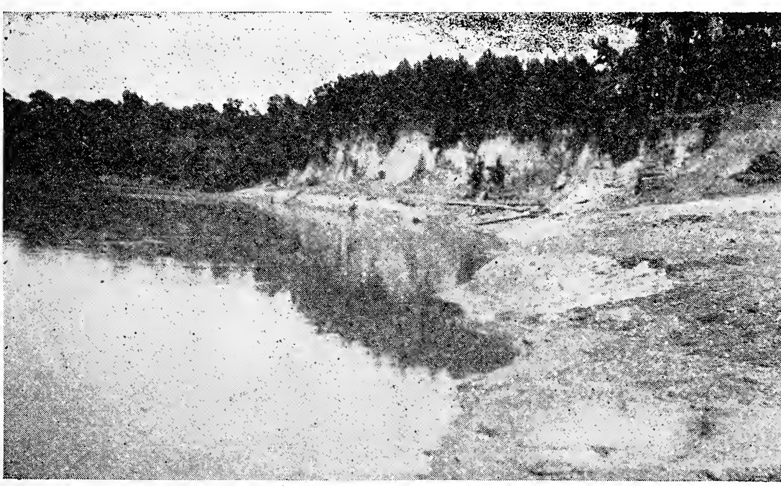

FIG. 27.—Clay exposed on the Apalachicola River at Estiffanulga Bluff, Liberty County.

Apalachicola rivers. Its surface exposures are sands, clays and marls of the Alum Bluff, Choctawhatchee and Pleistocene formations.

Flood-plain clays are common along the Ocklocknee and Apalachicola rivers. Two of these clays are found at Estiffanulga Bluff on the Apalachicola River. The section here is as follows:

Section at Estiffanulga Bluff, Apalachicola River.

	Feet.	Inches.
Soil		8
Clay (Top, Lab. Sample No. 0-39)	20	
Sand	3	
Clay (Bottom, Lab. Sample No. 0-46)	5 plus	

Only five feet of this lower clay are exposed above the river level. Its exact thickness is not known. Both of these clays are highly micaceous. Neither of them have been worked. The Apalachicola River offers water transportation to points northward and southward.

The top clay has excellent plasticity, working and drying qualities and burns to a light-red color at cone 010. This clay may be used for common or face brick, hollow-block ware, drain tile and red earthenware. Its physical properties are as follows:

Physical Properties of Estiffanulga Bluff Top Clay (Lab. No. 0-39).

Plasticity, judged by feel	Excellent.
Water of plasticity	30.65%
Pore water	0.45%
Shrinkage water	30.20%
Linear air shrinkage	9.10%
Volume air shrinkage	29.20%
Modulus of rupture, average	281.8 pounds per square inch.
Slaking test	20 minutes.
Steel hard at cone 05.	

Fire tests:

Temperature.	Linear Shr. Per Cent.	Absorption. Per Cent.	Porosity. Per Cent.	Color.
950°C.	1.9	23.55	41.30	Brick red.
1950	3.9	23.45	40.75	Brick red.
1150	6.9	14.95	30.90	Brick red.
1190	5.9	9.23	20.75	Brick red.
1230	5.9	9.39	21.10	Brick red.
1310	11.9	5.78	15.75	Brick red.

The lower clay is also highly plastic and has excellent working and drying qualities. It is cream-burning up to cone 12 where it changes to a gray. This clay may be used for stoneware and terra-cotta as well as a good grade of structural materials. It has the following physical properties:

Physical Properties of Estiffanulga Bluff Bottom Clay (No. 0-46).

Plasticity, judged by feel	Excellent.
Water of plasticity	29.45%
Pore water	0.45%
Shrinkage water	29.00%
Linear air shrinkage	8.30%
Volume air shrinkage	31.05%
Modulus of rupture, average	570.9 pounds per square inch.
Slaking test	24 hours.

Steel hard at cone 05.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	2.7	19.71	35.60	Cream.
1050	3.2	19.87	36.00	Cream.
1150	6.7	11.61	25.20	Cream.
1190	6.7	9.05	19.30	Cream.
1230	6.7	7.10	15.80	Cream.
1310	6.7	4.53	10.60	Cream.
1370	7.2	2.52	6.70	Gray.
1430	8.2	1.29	3.65	Gray.

MADISON COUNTY

Madison County lies in north Florida between the Suwannee and Aucilla rivers. It is underlain by the Alum Bluff and Chattahoochee formations. A mantle of red, sandy clay covers practically all of the county, but no clays suitable for manufacturing purposes are known.

MANATEE COUNTY

Manatee County is situated south of Tampa Bay on the west side of the peninsula. Its surface exposures are chiefly the Alum Bluff and Bone Valley formations.

The H. A. Graack and Sons Pottery in Bradentown uses a sandy clay dredged from the Manatee River. The clay is washed by hand before using.

A white, calcareous clay occurs east of Bradentown and occupies a more or less continuous area eastward to the vicinity of Gardner and Arcadia. An exposure on the property of W. J. McLaughlin, eight and one-half miles east of Bradentown, Sec. 28, Twp. 34 S., R. 19 E., shows the following section:

Section Exposed in Creek near Sawmill on W. J. McLaughlin Property.

	Feet.	*Inches.*
Soil		18
Clay, white (Lab. Sample No. 0-72)	4	6
Clay, white (Lab. Sample No. 0-19)	24 plus	

Both of these clays are cream-burning and retain a soft, porous texture up to their fusion points. The top clay melts at cone 12 and the lower one at cone 9. Neither of them are desirable for the manufacture of high-grade clay products. A light, soft, porous structural material of low strength may be made from the lower clay, but very careful grinding and mixing would be necessary. Both of these clays are high in soluble salts. The upper one contains 24.4 per cent lime and 6.63 per cent magnesia, as may be seen from the analysis given on the next page.

Its physical properties are:

Physical Properties of W. J. McLaughlin Top Clay (Lab. No. o-72).

Plasticity, judged by feel	Excellent.
Water of plasticity	29.10%
Pore water	0.19%
Shrinkage water	28.91%
Linear air shrinkage	4.80%
Volume air shrinkage	12.10%
Modulus of rupture, average	265.9 pounds per square inch.
Slaking test	10 minutes.

Overfires at cone 12.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.8	6.19	67.20	Cream.
1050	1.2	5.87	66.80	Cream.
1150	2.2	5.30	63.50	Cream.
1190	5.2	3.87	54.50	Cream.
1230	3.2	3.93	57.50	Cream.
1310	2.2	4.05	60.10	Cream.

The lower clay contains 9.1 per cent lime and 5.54 per cent magnesia, as may be seen from the analysis given below. Its physical properties are:

Physical Properties of W. J. McLaughlin Bottom Clay (Lab. No. o-19).

Plasticity, judged by feel	Excellent.
Water of plasticity	38.40%
Linear air shrinkage	12.70%
Volume air shrinkage	36.95%
Modulus of rupture, average	544.9 pounds per square inch.
Slaking test	3 days.

Overfires at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	26.45	48.75	Cream.
1050	2.3	26.20	47.50	Cream.
1150	4.8	25.80	43.30	Cream.
1190	4.3	20.75	43.40	Cream.
1230	6.3	16.75		

Chemical Analysis of W. J. McLaughlin Clays, A. M. Henry, Analyst.

	Lab. Numbers.	
	0-19	*0-72*
Silica (SiO_2)	54.95	34.55
Iron and Aluminum oxides	11.54	5.75
Calcium oxide (CaO)	9.10	24.40
Magnesium oxide (MgO)	5.54	6.63
Moisture at 100°C.	4.37	1.70
Both samples contain considerable organic matter.		
	85.50	73.03

The Bartow clay occurs in the northeastern part of the county. (For a discussion of Bartow clay see Polk County, page 195.) This area, however, is not accessible to transportation.

Fuller's earth occurs in the Alum Bluff formation and is mined at Ellenton on the north side of the Manatee River.

MARION COUNTY

Marion County is situated in the central part of the peninsula. Its western half is underlain chiefly by the Ocala and the eastern half by the Alum Bluff formation. Numerous outliers of the Alum Bluff and Alachua formations are found in the Ocala formation. The eastern part of the county extends to Lake George in the St. Johns River valley and includes flood-plain deposits. Marion County is partly in the Lake Region, and numerous lacustrine deposits, chiefly in sink-holes, are found locally.

Residual clays from the Ocala limestone are of common occurrence but few of them are of commercial importance. The losses from warping and cracking in drying and firing these clays are often excessive. In the northwestern part of the county, just across the county line from Williston in Levy County, are some residual clays having the same properties as the Williston School clay. (See Levy County, page 180.) Calcareous residual clays are found near Dunnellon, Summerfield, and Kendrick.

Sedimentary clays underlie extensive areas in the eastern part of the county. One of these is found in the region about Burbank. Here the clay is over eighteen feet deep and overlain by about one foot of sandy soil. The exact depth of the clay is not known.

This clay is red-burning, has good plasticity, works well and dries without difficulty. It may be used for common brick, hollow-block ware,

fireproofing and drain tile. The clay is slightly sandy and retains a distinctly porous texture at cone 16, hence a vitrified product could not be satisfactorily produced. A sample taken one-half mile south of Burbank on the Ocala Northern Railway has the following physical properties:

Physical Properties of the Burbank Clay (Lab. No. 0-20).

Plasticity, judged by feel	Excellent.
Water of plasticity	23.20%
Linear air shrinkage	10.60%
Volume air shrinkage	24.85%
Modulus of rupture, average	279.3 pounds per square inch.
Slaking test	20 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.1	13.20	31.95	Brick red.
1050	0.6	14.10	29.20	Brick red.
1150	0.6	12.40	29.75	Brick red.
1190	0.1	10.95	28.95	Brick red.
1230	1.4	10.42	28.20	Brick red.
1310	2.1	10.14	27.75	Brick red.
1370		10.07	26.85	Brick red.

A lacustrine clay underlies the region adjoining Lake Weir on the south. It is grayish to white in color, varies in thickness from three to seven feet, and is overlain by sand ranging from three to six feet in thickness. While this clay is only about one-half mile from a Seaboard spur, the heavy overburden precludes the deposits having any commercial value.

Coarse, sandy clay, suitable for sand-clay road material, is found in the southeastern part of the county.

MONROE COUNTY

Monroe County lies at the extreme south end of the peninsula and consists chiefly of Pleistocene limestone and sands. No clays are known in the county.

NASSAU COUNTY

Nassau County is situated in the extreme northeast corner of the State and lies between the St. Marys River and the Atlantic Ocean. The county is underlain mostly by sands and marls, but the central part of the county has some clay deposits. Flood-plain clays are found along the St. Marys River.

FIG. 28.—"Old Brick Yard Landing" on the St. Marys River, Nassau County. Formerly the site of a brick plant.

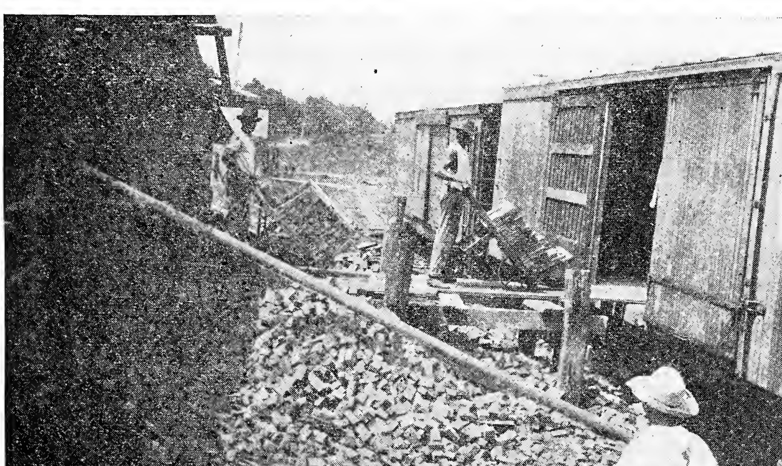

FIG. 29.—Loading cars, Callahan Brick and Tile Co., Callahan, Nassau County.

The Callahan Brick and Tile Company works a deposit, probably marine, ranging from eight to twenty feet in thickness and having an overburden of six or eight inches. This deposit is underlain in places by a marl. About twenty acres have been worked and about twenty acres more have been proven. The deposit probably underlies a much more extensive area.

The plant is located on the Seaboard Air Line Railway near its intersection with the Atlantic Coast Line Railroad. The product is shipped to points in south and west Florida. Both a common and a face brick are produced.

This clay may be used for common structural materials where a vitrified product is not essential. The fired product retains a porous texture at cone 15. Its physical properties are:

Physical Properties of Callahan Clay (Lab. No. o-29).

Plasticity, judged by feel...........	25.60%
Water of plasticity......	0.42%
Pore water	25.18%
Shrinkage water	11.70%
Linear air shrinkage...............	29.85%
Volume air shrinkage..............	805.2 pounds per square inch.
Modulus of rupture, average........	3 days.
Slaking test	Excellent.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.7	15.85	39.75	Brick red.
1050	1.3	15.70	39.00	Brick red.
1150	1.8	14.15	31.48	Brick red.
1190	2.2	12.60	30.25	Brick red.
1230	2.2	11.95	28.00	Brick red.
1310	2.2	11.58	26.75	Brick red.

A brick plant was formerly operated by the Callahan Brick and Tile Company about three-quarters of a mile south of Callahan. The clay worked is the same as is now being worked at Callahan.

The region northward between Callahan and the St. Marys River is practically all underlain by a slightly sandy clay.

A brick plant was formerly operated at the "Old Brick Yard Landing" on the St. Marys River, which is about forty miles west of Fernandina. Here there is an overburden of six to eight inches of soil, two feet of weathered, reddish clay, then a considerable depth of a grayish, plastic clay. Wells nearby indicate that this clay has a thickness of approxi-

mately forty feet. Water transportation via the St. Marys River is available at this point.

Other brick plants have been operated about seven miles east of Callahan, at Yulee, and at Fernandina.

OKALOOSA COUNTY

Okaloosa County is located in western Florida and extends from the Florida-Alabama line to the Gulf of Mexico. The formations consist of the Alum Bluff in the northeast corner and undifferentiated sands and marls in the remainder of the county. Much of the surface is covered by a sand-clay mantle. No clays adapted to manufacturing uses are known in the county.

OKEECHOBEE COUNTY

Okeechobee County lies just north of Lake Okeechobee and east of the Kissimmee River. Pleistocene sands and marls form the surface materials. No clays of commercial importance are known to be present.

ORANGE COUNTY

Orange County is situated in the east-central part of the peninsula and lies within the Lake Region. Its surface formations are Alum Bluff and Pleistocene sands and marls. Reddish and brownish sandy clays suitable only for sand-clay roads are of widespread distribution in the county.

A bluish-gray clay occurring about two miles east of Clarcona has been washed and found fairly satisfactory for some grades of work at the Orlando potteries. The overburden ranges from one to five feet of sand and the clay averages about three feet in thickness. The nearest railway is about two miles. The unwashed clay has the following physical properties:

Physical Properties of the Clarcona Clay (Lab. No. o-60).

Plasticity, judged by feel	Excellent.
Water of plasticity	22.50%
Pore water	0.16%
Shrinkage water	22.34%
Linear air shrinkage	6.90%
Volume air shrinkage	19.80%
Modulus of rupture, average	133.1 pounds per square inch.
Slaking test	3 days.

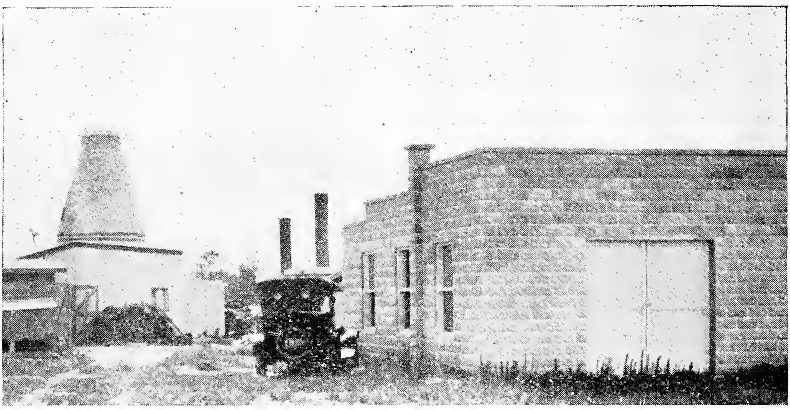

FIG. 30.—Orlando Pottery, Orlando, Orange County.

FIG. 31.—A potter at work, Orlando Pottery, Orlando, Orange County.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.6	19.57	37.40	Cream.
1050	1.1	20.52	38.80	Cream.
1150	1.6	18.93	35.80	Cream.
1190	3.1	16.47	32.80	Cream.
1230	4.1	15.31	33.10	Cream.

Flood-plain clays are exposed on the bank of the Econlockhatchee River, seven and one-half miles east of Winter Park, on the property of P. A. J. Nelson. A section of this exposure is as follows:

Section of Clay Strata on Econlockhatchee River on Nelson Property, East of Winter Park.

	Feet.
Sand, surface	3
Clay, brown, plastic	2
Clay, brown, sandy	3
Clay, gray, jointed	1
Sand	?

This deposit is located about two miles from the Florida East Coast Railway. The heavy overburden and the thickness of the clay does not warrant commercial exploitation.

Numerous lacustrine deposits are found in Orange County. One of these, suitable for common brick, is exposed on the west side of Lake Ola, but its distance from transportation renders it of doubtful commercial importance.

A sample from city pit in the city of Orlando was tested by the United States Bureau of Standards in 1914 with the following results:[1]

Physical Properties of Orlando City Clay (Bureau of Standards Sample No. 14).

Plasticity	Poor.
Water of plasticity	19.9 %
Linear air shrinkage	2.55%

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.56	36.1	Red.
1020		36.4	Red.
1050		34.6	Red.
1080		35.2	Red.
1100		35.3	Red.
1110	0.41		Red.
1140		35.2	Red.
1170		35.8	Red.
1200		35.6	Red.
1230	0.58	35.3	Red.
1260		36.4	Red.
1290		36.0	Red.
1320	0.56	35.2	Red.

This clay is of no value for the manufacture of clay products.

OSCEOLA COUNTY

Osceola County lies in the southeastern edge of the Lake Region and is underlain by Pleistocene sands and marls. A few clays are in-

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[1]Sellards, E. H., Report on Tests for Paving Brick, Florida Geological Survey Press Bulletin No. 7, 1915.

terbedded with the marls. Few of these, however, have sufficient thickness and extent to warrant commercial exploitation.

A brick plant was formerly operated near the Fair Grounds at Kissimmee. The clay is suitable for only a poor grade of common building-brick. The deposit is located on the Atlantic Coast Line Railroad. Its physical properties are:

Physical Properties of Kissimmee Fair Grounds Clay (Lab. No. 0-63).

Plasticity, judged by feel	Good.
Water of plasticity	24.45%
Pore water	0.30%
Shrinkage water	20.15%
Linear air shrinkage	4.70%
Volume air shrinkage	15.75%
Modulus of rupture, average	271.5 pounds per square inch.
Slaking test	1 hour.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.7	17.57	38.80	Brick red.
1050	0.3	18.61	40.10	Brick red.
1150	1.7	11.92	33.80	Brick red.
1190	2.3	10.09	30.20	Brick red.
1230		8.94	25.75	Brick red.

PALM BEACH COUNTY

Palm Beach County is located between Lake Okeechobee and the Atlantic Ocean. Its formations are Pleistocene limestones and sands. No clays of importance are known to be present.

PASCO COUNTY

Pasco County is located on the west side of the central portion of the peninsula. The Tampa and Ocala formations compose the surface materials with a very coarse sand-clay of unknown age forming a mantle of variable thickness over much of the county.

The coarse, sandy clay is reddish to brownish in color and at times has relatively high clay content. It has a thickness of as much as thirty feet or more in the region southwest of Dade City and near San Antonio. Some of this material is now being used for molding sand. It is also extensively used in the county for sand-clay road material. It has no value for the manufacture of clay products.

Sedimentary kaolin occurs in numerous places in the vicinity of Dade City and in at least one point near San Antonio. For a full discussion of this clay see Chapter IX.

A grayish-brown, sandy clay occurs on the property of the Crystal Springs Colony near Crystal Springs. It contains some cherty fragments. This clay is red-burning and has good plasticity and working qualities. Soluble salts are present to a detrimental extent and form an irregular white efflorescence on the ware when exposed to moisture. If precautions are taken to overcome the soluble salts this clay may be used for a fair grade of common brick, but the production of a vitrified product would be impracticable. Its physical properties are:

Physical Properties of Crystal Springs Clay (Lab. No. o-69).

Plasticity, judged by feel	Excellent.
Water of plasticity	20.60%
Pore water	5.35%
Shrinkage water	15.25%
Linear air shrinkage	9.4 %
Volume air shrinkage	28.8 %
Modulus of rupture, average	317.7 pounds per square inch.
Slaking test	10 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.4	14.31	31.90	Brick red.
1050	0.6	13.40	32.80	Brick red.
1150	1.0	12.02	31.80	Brick red.
1190	1.0	12.39	30.40	Brick red.
1230	1.6	12.30	28.65	Brick red.
1310	2.4	12.98	22.80	Brick red.

A gray, plastic clay occurs one mile north of Dade City, between the Seaboard track and the highway. This clay is irregular in extent, is underlain by limestone and averages about nine feet in thickness. The overburden consists of about two feet of sandy soil.

This clay has a high air-shrinkage and cracks badly in drying and burning. It is not desirable for the manufacture of burned products. Its physical properties are:

Physical Properties of Seaboard Clay, Dade City (Lab. No. o-22).

Plasticity, judged by feel	Fair.
Water of plasticity	52.90%
Linear air shrinkage	13.90%
Volume air shrinkage	40.45%
Modulus of rupture, average	180 pounds per square inch.
Slaking test	3 minutes.

Overfires at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	3.1	8.92	23.20	Salmon.
1050	3.1	9.10	21.50	Salmon.
1150	4.1	8.25	20.45	Gray.
1190	4.1	7.45	16.00	Gray.
1230	5.1	6.60	14.50	Gray.

PINELLAS COUNTY

Pinellas County is located on the Pinellas Peninsula, which lies between Tampa Bay and the Gulf of Mexico. It is underlain by sands and marls with some interbedded clays of the Tampa, Alum Bluff and Caloosahatchee formations.

Some phosphatic clays are exposed on the Gulf coast and in Curlew Creek north of Dunedin. These are not suited for use in the manufacture of burned products.

A gray, sandy clay is found near Alligator Creek, one-half mile west of Coachman on the Tampa and Gulf Coast Railroad. The clay is approximately twenty-four feet thick and is overlain by three feet of sand. This clay may be used for the manufacture of a fair grade of common brick. A vitrified product, however, could not be produced.

A bluish-gray clay is exposed at the edge of Old Tampa Bay and extends around to the vicinity of Safety Harbor. This clay contains organic matter and some soluble salts and swells badly upon firing.

POLK COUNTY

Polk County is situated in the south-central part of the peninsula. The Alum Bluff and Bone Valley formations comprise the chief surface materials. The northern and eastern part of the county has a heavy coating of coarse, sandy clay, suitable only for sand-clay road material.

The Bartow clay, the sandy clay stratum overlying the Land Pebble Phosphate horizon, is of widespread occurrence in the southwestern part of the county. The term, Bartow clay, was formerly applied to the matrix carrying the pebble phosphate, but now the application of this term is limited to the sandy clay overlying the phosphate horizon. It is removed as overburden in the phosphate mines of this region.

The Bartow clay ranges in thickness from three to twelve feet. Its high sand content renders molding and handling difficult. This clay may be used only in the manufacture of common brick. It makes a porous,

buff-colored product at cones 010 and 05, and burns to a more dense texture and reddish color at cone 1. It fuses at cone 5.

Several samples of the Bartow clay were examined. These indicate that it is very uniform in its physical properties. The following sample taken from one of the phosphate mines near Bartow has the following physical properties:

Physical Properties of the Bartow Clay (Lab. No. o-53).

Plasticity, judged by feel	Fair.
Water of plasticity	20.10%
Pore water	0.00%
Shrinkage water	20.10%
Linear air shrinkage	5.00%
Volume air shrinkage	11.20%
Modulus of rupture, average	195.3 pounds per square inch.
Slaking test	24 hours.

Steel hard at cone 3.
Overfires at cone 5.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.00	18.57	37.10	Buff.
1050	0.00	16.38	36.00	Buff.
1150	0.00	12.84	31.20	Gray.
1190	3.00	10.60	27.00	Gray.
1230	3.00			Gray.

Numerous lacustrine deposits are found throughout the eastern part of the county. These deposits are usually local and of limited extent.

In the eastern part of the county is a well-defined, irregular ridge, extending from Haines City southward beyond Frostproof. Immediately west of this ridge are several thin sedimentary clays. These strata frequently have considerable areal extent, but they are too thin to warrant commercial exploitation. A section made on the Highlands Farms, four miles north of Lake Wales, which will serve as an example, is as follows:

Section Made in Clay-Bearing Strata on Highland Farms, Lake Wales.

	Feet.	*Inches.*
Sand	3	
Clay, gray, sandy	1	
Clay, grayish red		1
Clay, gray, sandy	1	
Clay, gray, jointed	1	6
Sand, red	?	

Two sandy clays occur at the "Y" on the Seaboard tracks as they enter Lake Wales. A section here is:

Section of Clay Strata at Seaboard "Y" at Lake Wales.

	Feet
Sand	3
Clay, gray, sandy	5
Clay, black	3

These two clays have similar properties. Both are sandy and are suited for nothing more than a very poor grade of common brick. The black, lower clay has the following physical properties:

Physical Properties of Seaboard "Y" Black Clay, Lake Wales (Lab. No. 0-51).

Plasticity	Fair.
Water of plasticity	19.50%
Pore water	0.63%
Shrinkage water	18.87%
Linear air shrinkage	6.90%
Volume air shrinkage	15.30%
Modulus of rupture, average	135.3 pounds per square inch.
Slaking test	24 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.9	15.80	33.75	Cream.
1050	2.5	15.58	34.40	Cream.
1150	2.9	14.68	32.60	Cream.
1190	2.9	14.54	31.60	Cream.

A sample of clay from the Peace Valley Farms Company's property, near Winter Haven, was tested by the Bureau of Standards in 1914.[1]

The results indicate that this clay is suitable only for a poor grade of common brick. Its physical properties are:

Physical Properties of Peace Valley Farms Clay, Bureau of Standards. (Sample No. 22).

Plasticity, judged by feel	Fair.
Water of plasticity	24.9 %
Linear air shrinkage	6.28%

[1]Sellards, E. H., Report on Tests for Paving Brick, Florida Geol. Survey Press Bulletin No. 7, 1915.

(Bricks were made some twenty years ago from a whitish marly clay just east of Carter's on the Atlantic Coast Line, near the head of the Peace River, but the venture does not seem to have been a success. R. M. Harper.)

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.37		35.6	Red.
1010			35.8	Red.
1040			35.6	Red.
1070			36.0	Red.
1100	0.47		34.8	Red.
1130			33.8	Red.
1160			33.8	Red.
1190			33.7	Red.
1220	0.08		33.6	Red.
1250			33.7	Red.
1280			33.4	Red.
1310	0.24		33.6	Red.

PUTNAM COUNTY

Putnam County lies in the St. Johns River valley in the north-eastern part of the State. The western part of the county is underlain by the Alum Bluff formation. Pliocene and Pleistocene sands and marls underlie the eastern part of the county. Flood-plain clay deposits are common along the St. Johns River. Lacustrine deposits are widely scattered over the county. The sedimentary kaolin occurs at several points in the southwestern part of the county. These are described in Chapter IX.

Several brick plants have formerly been operated in the region around Palatka. The clays were all St. Johns River flood-plain clays.

A clay formerly worked by the Utica Brick and Tile Company at Rice Creek Station may be used for common brick, face brick, hollow blocks, fireproofing, and drain tile. This deposit adjoins the Atlantic Coast Line Railroad and is located about 100 yards south of the station. Its physical properties are:

Physical Properties of Rice Creek Station Clay (Lab. No. 0-42).

Plasticity, judged by feel...........	Excellent.
Water of plasticity.................	24.20%
Pore water	0.50%
Shrinkage water	23.70%
Linear air shrinkage...............	7.7 %
Volume fire shrinkage..............	30.5 %
Modulus of rupture, average........	776.3 pounds per square inch.
Slaking test	6 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	12.26	30.40	Brick red.
1050	0.3	13.92	30.60	Brick red.
1150	0.3	12.55	28.00	Brick red.
1190	0.3	11.60	26.00	Brick red.
1230	1.3	10.83	26.40	Brick red.
1310		11.50	28.60	Brick red.
1370		11.01	28.00	Brick red.
1430		8.19	19.10	Brick red.

The old Herman Brown brick plant was located on Rice Creek, about three miles southwest of Rice Creek Station in Sec. 16, T. 9 S., R. 26 E. Common brick, hollow block and drain tile were produced. This deposit is located three miles west of the Atlantic Coast Line Railroad and two miles north of the Georgia Southern and Florida Railroad. The abandoned plant was located on the bank of the creek which offers water transportation facilities to Jacksonville and other points on the St. Johns River.

The clay is twelve feet thick, underlain by sand and has an overburden of about one foot of soil. The exact extent of this deposit is not known, but more than forty acres are known to be underlain by it.

A vitrified product cannot be produced, but this clay is suitable for the manufacture of a good grade of structural materials. Its physical properties are:

Physical Properties of Herman Brown Clay, Rice Creek (Lab. No. o-62).

Plasticity, judged by feel..........	Excellent.
Water of plasticity................	22.25%
Pore water	1.32%
Shrinkage water	20.93%
Linear air shrinkage..............	10.0 %
Volume fire shrinkage.............	26.45%
Modulus of rupture, average........	546.2 pounds per square inch.
Slaking test	3 hours.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	13.11	36.50	Brick red.
1050	1.0	13.12	36.20	Brick red.
1150	2.0	13.23	34.16	Brick red.
1190	2.6	11.08	31.70	Brick red.
1230	2.1	11.79	28.70	Brick red.
1310	3.0	12.34	30.70	Brick red.

A similar clay exposed about one-half mile north of Springside, Sec. 29, T. 9 S., R. 26 E., may also be used for a good grade of structural materials. It has an overburden of about one foot, ranges from twelve to twenty feet in thickness and underlies an extensive area in this region. This clay adjoins the Georgia Southern and Florida Railroad at Springside. A sample taken one-half mile north of the station has the following physical properties:

Physical Properties of Springside Clay (Lab. No. 0-44).

Plasticity, judged by feel...........	Excellent.
Water of plasticity.................	25.10%
Linear air shrinkage...............	11.1 %
Volume air shrinkage..............	28.57%
Modulus of rupture, average........	791.4 pounds per square inch.
Slaking test	1 hour.
Overfires at cone 12.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.1	12.60	29.70	Brick red.
1050	0.9	13.70	31.00	Brick red.
1150	0.6	12.31	29.40	Brick red.
1190	1.4	11.45	29.75	Brick red.
1230	1.4	10.44	25.75	Brick red.
1310	1.4	8.69	17.50	Dark red.

Numerous other good common-brick clays occur in the region between Crescent City and Lake George. A brick plant was formerly operated at Denver where a common brick was made. Some of these clays are very similar in properties to those west of Palatka, and others seem to be identical with the Shell Bluff clay, found on the opposite side of Crescent Lake in Flagler County. (See Shell Bluff Clay, page 158.)

Sandy clays, which may be used for a fair grade of common brick, are also found on the east side of the St. Johns River, near Orange Mills and San Mateo.

ST. JOHNS COUNTY

St. Johns County lies in northeastern Florida, between the St. Johns River and the Atlantic Ocean. It is underlain principally by undifferentiated sands and marls with a few interbedded clays of limited areal extent and thickness.

Some good clays are found in the southwestern part of the county in the vicinity of Hastings. One of these occurs on the property of J. T. Minton, about one mile southeast of Hastings. This deposit consists of four feet of a gray clay overlain by one foot of soil. A marl underlies the clay. This deposit has been proven on forty acres at this place.

This clay may be used for a good grade of common and face brick. It may equally well be used for common structural materials. It has the following physical properties:

Physical Properties of Minton Clay, Hastings (Lab. No. 0-33).

Plasticity, judged by feel	Excellent.
Water of plasticity	23.55%
Pore water	0.41%
Shrinkage water	23.14%
Linear air shrinkage	11.2 %
Volume fire shrinkage	31.2 %
Modulus of rupture, average	837.7 pounds per square inch.
Slaking test	2 minutes.

Steel hard at cone 1.
Overfires at cone 5.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.7	20.40	35.75	Brick red.
1050	1.2	11.40	27.40	Brick red.
1150	1.2	10.80	26.50	Brick red.
1190	2.2	8.55	25.50	Brick red.
1230	2.3	8.30	22.50	Brick red.

Sandy clays occur along the east bank of the St. Johns River. These are flood-plain clays of variable extent and thickness and are suitable only for an inferior grade of common brick. One of these clays exposed four miles east of Picolata on the St. Augustine road has the following section:

Section of Clay Strata near Picolata.

	Feet.
Soil	1
Clay, red, sandy	10
Sand, grayish with clay	?

A similar clay occurring on the property of J. J. Goss, near Riverdale, has the following physical properties:

Physical Properties of J. J. Goss Clay, Riverdale (Lab. No. o-77).

Plasticity, judged by feel	Excellent.
Water of plasticity	21.15%
Pore water	0.40%
Shrinkage water	20.75%
Linear air shrinkage	6.5 %
Volume fire shrinkage	16.1 %
Modulus of rupture, average	211.9 pounds per square inch.
Slaking test	10 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.0	28.98	38.90	Brick red.
1050	1.5	27.72	35.50	Brick red.
1150	2.5	20.48	29.20	Brick red.
1190	2.5	19.30	27.60	Brick red.
1230	2.5	19.04	25.60	Brick red.

ST. LUCIE COUNTY

St. Lucie County is located just northeast of Lake Okeechobee and borders the Atlantic Ocean. It is underlain by marls and sands of Pleistocene age. No clays of importance are known.

SANTA ROSA COUNTY

Santa Rosa County is situated in west Florida just east of the Escambia River and extends from the Alabama boundary to the Gulf of Mexico. The surface formations are sands, marls and clays, ranging from Pleistocene to Recent in age. The Citronelle formation underlies portions of the western part of the county.

The clays of Santa Rosa County have, in the past, been practically unworked. This lack of development is largely due to the absence of transportation facilities in those sections of the county where the clays of greatest promise occur. The Louisville and Nashville Railroad traverses the southern part of the county from east to west, and the Florida and Alabama Railroad extends from Milton northeastward into Alabama, but the clays most suitable for commercial uses lie in the northwestern part of the county.

The Board of Trustees of the Allentown Consolidated School District, nine miles north of Milton, have followed a novel procedure to

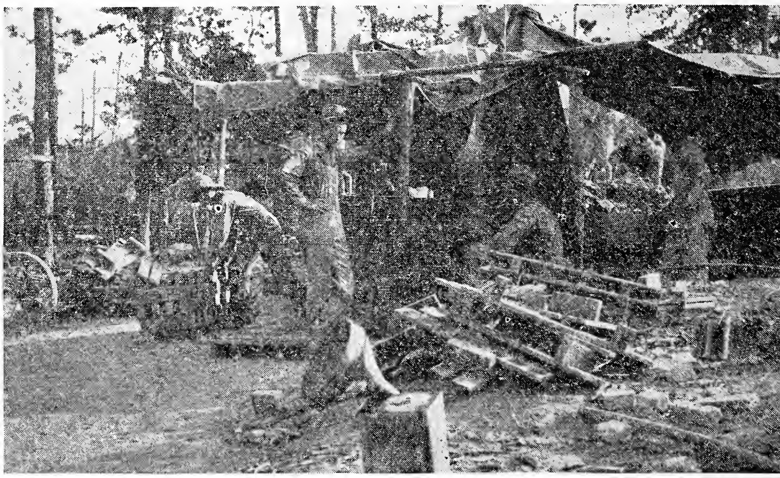

FIG. 32.—Portable press in operation. Allentown Consolidated School, near Milton, Santa Rosa County.

provide brick for the erection of a modern school building. They have employed G. H. Murphy, of the Glendale Brick Works, Glendale, to make for them 400,000 brick. They plan to use half of this brick in the construction of the building and sell the remaining half to defray the expenses of manufacture. More than the 200,000 allotment to be sold had been engaged by local citizens at the time the scheme was put into operation. Most of the work necessary in the manufacture of the brick is being donated by residents of the community.

Mr. Murphy has opened up a clay-pit about one-half mile from the site of the school building. He is using a portable press and cutting machine which is drawn by a tractor. The tractor is also used to furnish the power when the press is in operation.

Two clays are dug by scrapers and molded immediately in the press. The green brick are stacked out in the open to dry with no protection whatever from rain, wind or sunshine and when dry are burned in temporary scove kilns of 50,000 capacity. Drying is completed in three days.

Those interested in this enterprise are exceedingly fortunate in having a clay close at hand which can stand such rapid, crude and un-

protective treatment without serious losses. The percentage of loss here is incredibly low.

The clay deposit, which is probably the Citronelle formation, is sedimentary and consists of two strata. The upper one has a slight amount of sand, is brownish in color, and is about two feet in thickness. The lower one is gray in color, free from sand but has a slight amount of mica. Its thickness is unknown. The deposit is overlain by about two feet of sand and soil, which is removed. The proportion of the two clays used in the Allentown brick is one part of the upper brown one to two parts of the lower gray clay.

This deposit of clay has an extensive distribution in this vicinity and probably is connected with the deposits of similar clay farther westward in Escambia County.

Either of these clays may be used for stoneware, terra-cotta, or roofing tile. The small amount of sand in the upper clay should be washed out before it is used for the better grades of ware. The upper clay has the following physical properties:

Physical Properties of Allentown Top Clay (Lab. No. 0-14).

Plasticity, judged by feel	Excellent.
Water of plasticity	29.90%
Linear air shrinkage	8.6 %
Volume fire shrinkage	24.2 %
Modulus of rupture, average	324.2 pounds per square inch.
Slaking test	20 minutes.

Steel hard at cone 1.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.9	20.20	38.90	Pink.
1050	1.6	17.10	33.25	Pink.
1150	6.9	8.55	19.80	Gray.
1190	6.9	7.08	17.25	Gray.
1230	6.9	6.85	15.60	Gray.
1310	8.9	3.14	8.85	Gray.
1370	9.9	1.55	8.45	Gray.
1430	9.9	1.12	4.72	Gray.

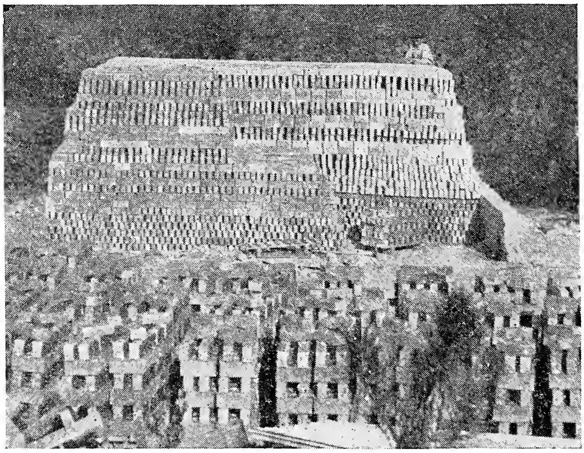

FIG. 33.—Partially built scove kiln in rear ground with freshly molded brick stacked out in open air to dry in foreground. Allentown Consolidated School, ten miles north of Milton, Santa Rosa County.

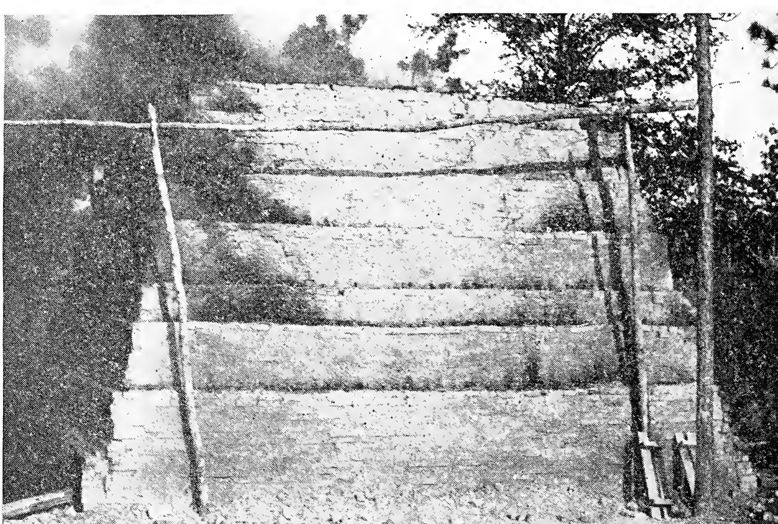

FIG. 34.—Firing a scove kiln. Allentown Consolidated School, ten miles north of Milton, Santa Rosa County.

The lower clay has the following physical properties:

Physical Properties of the Allentown Lower Clay (Lab. No. o-81).

Plasticity, judged by feel	Excellent.
Water of plasticity	24.15%
Pore water	0.65%
Shrinkage water	23.50%
Linear air shrinkage	8.0 %
Volume air shrinkage	30.6 %
Modulus of rupture, average	244.6 pounds per square inch.
Slaking test	10 minutes.
Steel hard at cone 1.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.0	21.99	38.20	White.
1050	2.0		36.20	White.
1150	5.0	15.98	18.60	Brown.
1190	7.0	10.28	15.50	Brown.
1230	7.0	9.60	10.50	Gray.
1310	7.0	2.25	6.15	Gray.
1370	9.5	2.00	5.95	Gray.
1430	8.0	1.52	4.75	Gray.

A sample of clay taken from Blackwater Creek, two and one-half miles northeast of Milton, was tested by the Bureau of Standards in 1914.[1]

Its physical properties indicate that it may be used for a good grade of common structural materials, but not for a vitrified product. It has the following physical properties:

Physical Properties of Blackwater Creek Clay (Bureau of Standards, Sample No. 3).

Plasticity	Excellent.
Water of plasticity	28.9%
Linear air shrinkage	6.0%

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption.*	*Porosity. Per Cent.*	*Color.*
850°C.	0.64		35.30	Salmon.
950			35.80	
980			36.20	
1010	0.21		34.86	
1040			33.60	Buff.
1070			32.15	
1100			31.10	
1130	1.44		29.55	
1160			29.05	
1190			28.80	
1220			28.05	
1250	1.17		27.30	

[1]Sellards, E. H., Report on Tests for Paving Brick, Florida Geol. Survey Press Bulletin No. 7, 1915.

SARASOTA COUNTY

Sarasota County is situated in southwest Florida and borders on the Gulf coast just above Charlotte Harbor. Its surface materials are chiefly sands and marls. No important clay deposits are known within reasonable distance from transportation.

SEMINOLE COUNTY

Seminole County is located in the east-central part of the peninsula in the upper St. Johns Valley. Sandy surface clays containing a coarse quartz sand and very desirable for sand-clay roads are widely distributed over the county. No clays suitable for manufacturing products are known.

SUMTER COUNTY

Sumter County is located in the west-central part of the peninsula and is bordered on the west by the Withlacoochee River. The Ocala, Tampa and Alum Bluff formations comprise the greater part of the surface materials. These consist chiefly of sands and sandy clays.

Residual clays from the Ocala limestone occur locally in the northern part of the county. Few of these, however, may be used for manufactured products.

A few somewhat sandy clays of limited extent occur in the eastern part of the county. One of these is found at the Atlantic Coast Line station at Webster. It probably underlies a considerable area and is more than four feet in thickness. The overburden is about three feet of sand and soil. Only a soft, porous building brick of very inferior quality can be made from this clay. It has the following physical properties:

Physical Properties of the Webster Clay (Lab. No. 0-75).

Plasticity, judged by feel...........	Good.
Water of plasticity.................	25.90%
Pore water	1.55%
Shrinkage water	24.35%
Linear air shrinkage...............	10.8 %
Volume air shrinkage..............	29.6 %
Modulus of rupture, average........	328.5 pounds per square inch.
Slaking test	5 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.8	14.79	33.20	Reddish brown.
1050	0.8	14.80	33.60	Reddish brown.
1150	0.8	14.37	33.10	Reddish brown.
1190	0.8	14.53	32.00	Reddish brown.
1230	0.8	14.95	21.50	Reddish brown.

SUWANNEE COUNTY

Suwannee County is located in north Florida and is underlain by the Ocala, Chattahoochee and Alum Bluff formations. A sand-clay mantle covers most of the county and may be used for road material.

Residual clays from both the Ocala and the Chattahoochee limestones occur locally, but none of these are desirable for use in burned products.

Sandy clays occur commonly in the central and eastern parts of the county. Some of these may be used for a poor grade of common brick. A red-mottled clay, occurring one mile north of Live Oak on the property of W. H. Lyle, was tested by the Bureau of Standards in 1914,[1] and has the following physical properties:

Physical Properties of W. H. Lyle Clay (Bureau of Standards, Sample No. 6).

Plasticity	Good.
Water of plasticity	40.5%
Linear air shrinkage	11.79%

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	2.39	33.27	Light red.
1010		31.45	Light red.
1040		29.00	Light red.
1070		24.70	Light red.
1100	5.68	24.37	Dark red.
1130		24.65	Dark red.
1160		23.85	Dark red.
1190		24.70	Dark red.
1220	5.89	24.67	Dark red.
1250		24.53	Dark red.
1280		23.96	Dark red.
1310	5.62	24.65	Dark red.

TAYLOR COUNTY

Taylor County lies in north Florida and borders on the Gulf of Mexico. It is underlain chiefly by the Chattahoochee formation. Some

[1]Sellards, E. H., Report on Tests for Paving Brick, Florida Geol. Survey Press Bulletin No. 7, 1915.

clays occur in this region, but they are unfitted for use in manufactured products.

UNION COUNTY

Union County is located in the northern part of the peninsula. Sandy clays are of common occurrence, but none in which the clay content is high enough for use in burned products.

VOLUSIA COUNTY

Volusia County is situated in the north-central part of the peninsula and lies between the St. Johns River and the Atlantic Ocean. The western part of the county is underlain principally by the Nashua marl. Sands, clays and marls comprise the surface formations. Some flood-plain clays occur near Lake George in the northwestern part of the county.

The eastern part of the county has a heavy mantle of Pleistocene sands. One very small clay deposit was worked for common brick long ago on the coast, two miles north of Ormond Beach. The deposit is now covered by a sand dune and only parts of the dismantled machinery may be seen.

A marl-pit in the south part of the city of DeLand contains an overburden of thin sedimentary clays interbedded with sands and marls. It has the following section:

Section in Marl Pit, South Part of DeLand.

	Feet.	Inches.
Sand	3 to 6	
Clay, red, sandy	1	6
Clay gray, sandy	2	
Clay, gray, jointed		8
Shells		3
Clay, gray, brown	1	6
Shells		10
Marls	?	

A sample of each of the two lower gray clays, which are separated by three inches of shells, was mixed in equal proportions and tested. The overburden over these clays is sufficiently great to preclude their having any commercial importance in themselves, but as this material

is now removed in order to obtain the underlying marl for road purposes, this clay might be of some value as a by-product.

This mixture has excellent drying and working qualities, is red-burning, and would be suitable for a good grade of structural materials. The shells associated with these two clays are detrimental and would necessarily have to be removed or very finely ground. The physical properties are:

Physical Properties of DeLand City Clay (Lab. No. o-48).

Plasticity, judged by feel	Excellent.
Water of plasticity	29.90%
Pore water	6.12%
Shrinkage water	23.78%
Linear air shrinkage	13.0 %
Volume air shrinkage	38.0 %
Modulus of rupture, average	966.5 pounds per square inch.
Slaking test	30 minutes.
Steel hard at cone 010.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.0	11.40	27.95	Brick red.
1050	2.0	9.72	25.95	Brick red.
1150	2.0	9.96	25.20	Brick red.
1190	1.0	7.49	21.20	Brick red.
1230	0.5	12.51	26.75	Brick red.

A sandy clay, occurring in the northwest part of the city of DeLand, was formerly worked for common brick. The deposit consists of three feet of sand, three feet of red-mottled clay, and three feet of a buff clay, underlain by a sand.

This clay may be used for a porous, common brick. The physical properties are:

Physical Properties of Herman Brown Brick Yard Clay (Lab. No. o-35).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.70%
Pore water	0.00%
Shrinkage water	26.70%
Linear air shrinkage	10.7 %
Volume air shrinkage	27.75%
Modulus of rupture, average	306.4 pounds per square inch.
Slaking test	10 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	1.2	18.95	38.00	Cream.
1050	1.3	19.78	38.50	Cream
1150	1.3	17.30	38.30	Cream.
1190	1.2	17.42	38.50	Cream.
1230	1.3	18.22	35.75	Cream.
1310	1.3	15.20	35.00	Cream.
1430	1.7	15.58	34.80	Cream.

A brick plant was formerly operated about one-half mile south of the station at DeLeon Springs. The Volusia County Commissioners have opened a pit to obtain marl in the same deposit, one-quarter mile farther southward. The deposit consists of two feet of sand, four feet of gray, plastic clay. The clay is underlain by marl. It underlies an extensive area in the vicinity of DeLeon Springs. This clay may be used for a good grade of common structural materials. It has the following physical properties:

Physical Properties of Volusia County Shell and Marl Clay, DeLeon Springs (Lab. No. 0-70).

Plasticity, judged by feel...........	Excellent.
Water of plasticity................	20.10%
Pore water	1.90%
Shrinkage water	18.20%
Linear air shrinkage..............	8.0 %
Volume air shrinkage.............	25.7 %
Modulus of rupture, average........	532.3 pounds per square inch.
Slaking test	5 minutes.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.5	14.69	34.50	Brick red.
1050	0.5	14.30	34.00	Brick red.
1150	1.0	14.29	32.70	Brick red.
1190	1.0	14.33	31.10	Brick red.
1230	1.5	13.09	31.80	Brick red.
1370	1.5	12.16	32.25	Brick red.

The same conditions prevail a half-mile southward on the property of George LaFevre, except that the clay has a thickness of five feet and an overburden of only a few inches. The quality of the clay is the same. Several pits have been opened and a railway spur built to them. The clay is now being removed as an overburden in working the marl.

Another brick plant was formerly operated at Deep Creek, three miles north of DeLeon Springs. This deposit consists of an overburden

of three feet of sand and hardpan and five feet of blue, sandy, plastic clay which is underlain by marl. The clay has good working qualities and may be used for a good grade of common structural materials. Its physical properties are:

Physical Properties of Deep Creek Clay, DeLeon Springs (Lab. No. 0-74).

Plasticity, judged by feel	Excellent.
Water of plasticity	24.50%
Pore water	1.50%
Shrinkage water	23.00%
Linear air shrinkage	9.3 %
Volume air shrinkage	32.6 %
Modulus of rupture, average	635.0 pounds per square inch.
Slaking test	5 minutes.

Steel hard at cone 010.
Overfires at cone 9.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.7	12.19	27.80	Brick red.
1050	0.7	12.80	28.20	Brick red.
1150	0.7	10.39	26.00	Brick red.
1190	0.7	8.26	27.65	Brick red.
1230	1.2	7.82	27.00	Brick red.

WAKULLA COUNTY

Wakulla County, in middle Florida, is bordered on the south by the Gulf of Mexico and on the west by the Ocklocknee River. While the county is underlain by the Chattahoochee, Alum Bluff and Choctawhatchee formations, a heavy surface mantle of loose sand conceals them over much of the county.

No clays of importance are known in the county. A sample from the southwestern part of the county, submitted by S. B. Crowder to the State Geologist, was tested in 1920 by the Bureau of Standards.[1] The result of the test was as follows:

Plasticity	Fair.
Water of plasticity	30.0%
Linear air shrinkage	12.7%

Overfires at cone 10.
Fired color, dark brown.

WALTON COUNTY

Walton County is situated in west Florida, just west of the Choctawhatchee River, and extends from the Florida-Alabama boundary to

[1]Letter from Director U. S. Bureau of Standards to State Geologist of Florida, August 16th, 1920.

the Gulf of Mexico. It is underlain by the Chattahoochee, Alum Bluff, Choctawhatchee and Pleistocene formations. The same sandy-clay mantle, so commonly present in Florida, also covers much of Walton County.

A reddish and gray mottled clay is used at the Glendale Brick Works, at Glendale, in the production of common brick. This deposit is more than thirty feet in thickness and underlies at least forty acres, and probably more, in the vicinity of Glendale.

This plant is now operated only at intervals to supply local trade. Formerly a logging railroad connected this place with DeFuniak Springs and thus afforded an outlet for the product, but the railroad is now abandoned.

The clay is well suited for an excellent grade of common structural materials and red earthenware. Its physical properties are:

Physical Properties of Glendale Clay (Lab. No. o-11).

Plasticity, judged by feel...........	Excellent.
Water of plasticity..................	27.50%
Pore water	0.46%
Shrinkage water	27.04%
Linear air shrinkage...............	8.7 %
Volume air shrinkage..............	29.9 %
Modulus of rupture, average........	139.1 pounds per square inch.
Slaking test	
Steel hard at cone 1.	
Overfires at cone 16.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.2	20.20	37.20	Light red.
1050	1.3	20.50	37.15	Light red.
1150	5.8	18.80	28.20	Light red.
1190	5.8	11.58	19.35	Light red.
1230	5.8	8.35	20.75	Light red.
1310	6.3	5.30	17.10	Light red.
1370	6.8	4.68	15.30	Light red.
1430	8.3	4.65	14.20	Light red.

Mr. G. H. Murphy, who operates the Glendale Brick Works, and who was employed to manufacture the brick for the Allentown Consolidated School, in Santa Rosa County, (see page 202), is preparing to operate a brick plant on the property of R. J. Edwards in Sec. 14, Twp. 3 N., R. 18 W., three miles north of Argyle. Part of the machinery has already been installed.

This is a flood-plain deposit having a thickness of more than ten feet and a two-foot overburden of sand. The Louisville and Nashville Railroad, at Argyle, is the nearest shipping point.

The clay is red-burning and is suitable for a good grade of structural materials. Its physical properties are:

Physical Properties of Edwards Clay, Argyle (Lab. No. o-80).

Plasticity, judged by feel	Excellent.
Water of plasticity	26.40%
Pore water	1.01%
Shrinkage water	25.39%
Linear air shrinkage	8.00%
Volume air shrinkage	27.80%
Modulus of rupture, average	349.7 pounds per square inch.
Steel hard at cone 1.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	0.3	20.29	34.35	Brick red.
1050	1.0	20.77	36.85	Brick red.
1150	1.8	11.11	24.75	Brick red.
1190	7.0	9.00	21.40	Brick red.
1230	7.0	8.67	21.65	Brick red.
1310	7.0	8.21	21.86	Brick red.
1370	7.0	6.29	18.60	Brick red.
1430	9.0	0.65	8.45	Brick red.

A sandy surface-clay occurs on the property of Perry L. Biddle, one mile south of DeFuniak Springs. It burns to a friable and porous red-colored product and therefore is suitable only for a common brick of inferior quality.

A white, sandy, micaceous clay, containing some coarse quartz, occurs on the property of G. P. Billups in Sec. 26, T. 2 N., R. 19 W., five miles south of DeFuniak Springs on the Freeport road. The sand, mica and gravel content of this clay renders it useless for manufacturing purposes in its present form. It is probable that the clay would be of some value when washed. The nearest shipping point is DeFuniak Springs.

A black plastic clay occurs on the property of R. W. Thompson, one mile north of DeFuniak Springs. This stratum is ten feet in thickness and is overlain by twenty feet of sand. Sand also underlies the clay strata. This is a white-burning clay. Its exceedingly heavy overburden probably prevents it from having any commercial value at the present time.

WASHINGTON COUNTY

Washington County lies in west Florida and is bordered on the west by the Choctawhatchee River. It is underlain by the Chattahoochee, Alum Bluff, Choctawhatchee and Pleistocene formations.

The only clay of any value found in the county is a flood-plain deposit about two miles southwest of Chipley, which deposit is being worked by the Hall Brick Company for common brick. The nearest railway is two miles and practically all of the product is sold locally.

The deposit has been proven on about sixty acres and probably underlies a more extensive area. The clay stratum is about three feet in thickness, is overlain by six inches of soil and underlain by sand. The raw clay is black, fairly plastic and has good working qualities. It is cream-burning at the lower temperatures and changes to gray at about cone 1.

This clay is suitable in its present state for common structural materials such as face and common brick, hollow-block ware, drain tile, etc. It contains a small amount of coarse quartz sand and if this is washed out the clay may be used for stoneware, flower pots, turpentine cups, and similar articles. It has the following physical properties:

Physical Properties of Hall Brick Company Clay (Lab. No. 0-7).

Plasticity, judged by feel	Excellent.
Water of plasticity	28.80%
Pore water	1.13%
Shrinkage water	27.67%
Linear air shrinkage	9.00%
Volume air shrinkage	27.55%
Modulus of rupture, average	135.4 pounds per square inch.
Slaking test	20 hours.

Steel hard at cone 1.

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	2.0	21.75	30.80	Cream.
1050	2.5	20.10	30.50	Cream.
1150	5.0	11.90	26.40	Gray.
1190	6.0	9.30	21.50	Gray.
1230	8.0	6.10	21.02	Gray.
1310		4.80	13.10	Gray.
1370		3.84	12.75	Gray.
1430	12.0	2.59	8.55	Gray.

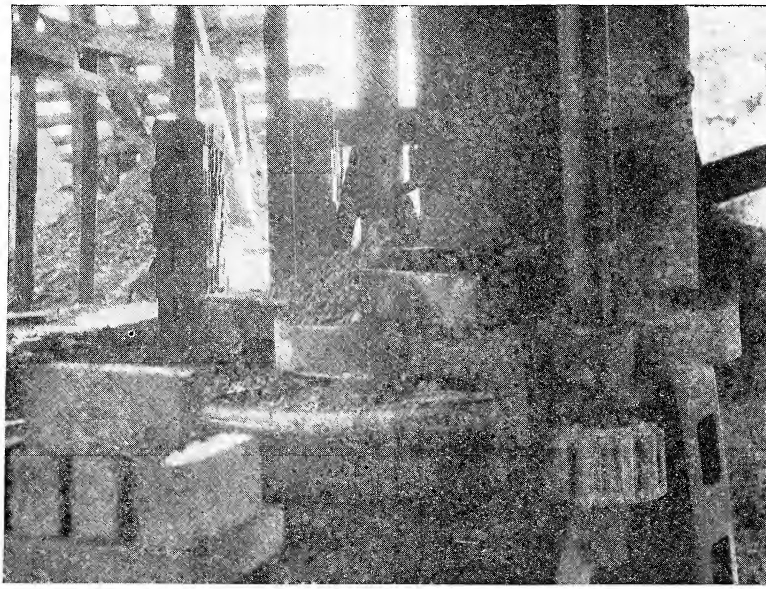

FIG. 35.—Brick machine, Hall Brick Company, Chipley, Washington County.

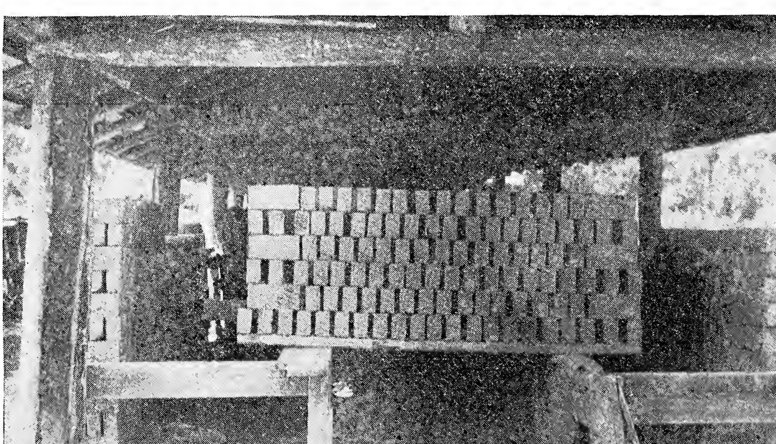

FIG. 36.—Drying shed, Hall Brick Company, Chipley, Washington County.

CHAPTER IX

SEDIMENTARY KAOLIN

The Florida clay which has attracted the greatest attention, both from a commercial and a scientific point of view, is the "sedimentary kaolin", found at a number of localities in the central part of the peninsula. This clay is of interest to the ceramist and the clay operator because of its wide field of uses and peculiar characteristics, and to the geologist because of its unique occurrence, distribution and association with other materials. Much has already been written about this unusual clay with reference to its nature, origin and geologic age without these problems being definitely solved. Its physical properties and uses, however, are fairly well known.

TERMINOLOGY

This clay has been variously known as ball-clay, china-clay, kaolin and plastic kaolin. It is commonly marketed under the name of plastic kaolin, or china-clay. The term china-clay is used broadly to include any white-burning clay, regardless of its origin. The term plastic kaolin is misleading in that it might include a residual deposit. The term kaolin is applied to a residual white-burning clay of high refractoriness and usually of low plasticity and bonding strength. A ball-clay is a plastic, sedimentary clay, white-burning, or nearly so, of high refractoriness, and usually good bonding strength.

None of these terms, therefore, are entirely satisfactory, as in chemical and physical properties the Florida clay is intermediate between a true kaolin and a ball-clay. Its chemical composition is essentially that of washed kaolins from other regions and its alumina content ranges from three to seven per cent higher than is the case in the typical ball-clays. The Florida clay also has a much higher plasticity, shrinkage and bonding strength than the true kaolin. In occurrence, composition and properties it is very similar to the white coastal plain clays of Georgia and South Carolina, except that the Florida clays must always be washed before being used.

The term "sedimentary kaolin" seems best suited for the white Florida clay, as this term shows the relationship to a true kaolin and

at the same time indicates the origin of the deposits in order to differentiate them from the typical or residual kaolins. The white-burning clays of the coastal plain of Georgia and South Carolina are likewise sedimentary kaolins.

DISTRIBUTION

The sedimentary kaolin is now being mined at two different localities. One of these is at Edgar, in Putnam County, and the other is near Okahumpka, in Lake County. Two companies are actively engaged in mining the clay near Okahumpka and one at Edgar.

The deposits of sedimentary kaolin are confined to the peninsular portion of the State and Sellards[1] states that the distribution of this material is co-extensive, or nearly so, with the Lake Region. Deposits have, however, been found well to the west of the Lake Region in Pasco, Hernando, Levy, and perhaps Citrus and Sumter counties, each of which, except Sumter, borders on the Gulf coast. Others have been reported in the vicinity of Live Oak in Suwannee County and also in Lafayette County, but nothing authentic is known about these occurrences at the present time. Sellards[2] further points out that the same type of topography occurs and is probably underlain by the same formations between the Suwannee and Choctawhatchee rivers. The occurrence of the sedimentary kaolin in the State may or may not be dependent upon its association with the Alum Bluff formation (Miocene).

While many of the plastic kaolin occurrences are in an Alum Bluff area, there is no evidence to indicate any genetic relation between the two; in fact, many of the occurrences are entirely outside the present Alum Bluff areas and are apparently in no way associated with that formation. On this basis, then, the probabilities of finding deposits of sedimentary kaolin between the Suwannee and Choctawhatchee rivers are poor. On the other hand, however, if the distribution of this clay is related to the present topography of the Lake Region, then, as Sellards intimates, there is some likelihood of finding deposits in north and west Florida.

In this connection it is interesting to note the occurrence in Sec. 26, T. 2 N., R. 19 W., five miles south of DeFuniak Springs in Walton County, of a sandy clay very closely resembling the crude

[1]Sellards, E. H., The Clays of Florida, Journal American Ceramic Society, Vol. I, p. 313, 1918.
[2]Loc. cit.

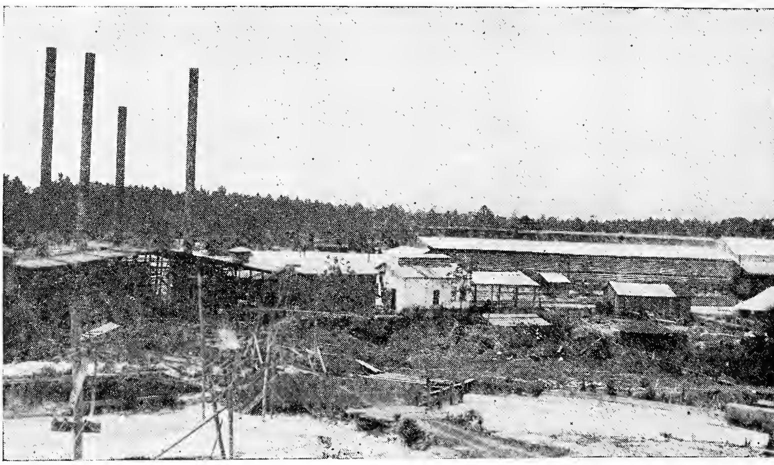

FIG. 37.—General View of Edgar Plastic Kaolin Company's Plant, Edgar, Putnam County.

sedimentary kaolin. This location is even west of the area mentioned by Sellards. Here the sand and mica content seems to be higher and the average size of the quartz pebbles larger than in the peninsula deposits. None of this material was washed and no chemical analyses are available to determine if it is actually a sedimentary kaolin.

Ries[1] has pointed out that in the northern extension of the sedimentary kaolin region the quartz pebbles are larger than is the case farther south. This would be natural to expect if the original source of the material is northward.

This may also account for the higher sand and mica content of the material in Walton County, if it is the same substance. In any case, its genesis and occurrence is much the same.

The deposits of sedimentary kaolin are of irregular outline and extent, rarely covering more than thirty acres. These individual deposits are often grouped together and separated only by a partition ranging from sixty to one hundred feet in width and composed of yellow, sandy clay, loose sand or hardpan probably indicating former stream-channels now filled with surface-sands and sandy clays.

[1]Ries, H., Clays of the United States East of the Mississippi River, U. S. Geol. Survey Prof. Paper No. 11, p. 82, 1903.

There are isolated occurrences of the sedimentary kaolin lying thirty or more miles from any other known deposits.

DESCRIPTION

The deposits themselves consist of a bed of white clay-bearing sand, which appears gray in its crude form, ranging from six to more than thirty feet in thickness and overlain by a deposit of loose surface-sand or soil which varies from six to twenty feet in thickness. Often where it has been exposed to weathering, the upper foot or so of the clay is stained with iron oxide. The deposit is very frequently cross-bedded, but as the stratification and laminations are of the same material and color, the cross-bedding is often indistinct. Some of these layers are conglomeratic and others have a much higher proportion of clay substance than the average.

The clay-bearing sand is underlain at different times by various materials, such as green clay, limestone, flint, fuller's earth, marl, or red-streaked clay. In some localities fuller's earth is reported to lie immediately underneath the green clay.

FIG. 38.—Removing overburden. Edgar Plastic Kaolin Company, Putnam County. Photo by H. Ries.

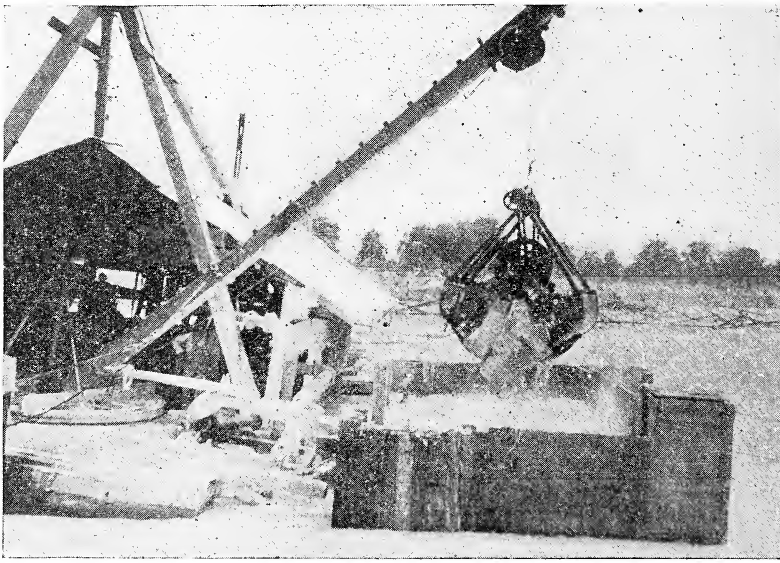

FIG. 39.—Dipper on dredge boat dropping crude clay into bin from which it is pumped up to washing plant. Edgar Plastic Kaolin Company, Edgar, Putnam County. Photo by H. Ries.

FIG. 40.—Trough leading to settling vat. Edgar Plastic Kaolin Co., Edgar, Putnam County. Photo by H. Ries.

GEOLOGIC AGE

The age of the sedimentary kaolin is not known. Matson[1] places it provisionally in the Pliocene with a query. Ries[2] lists it under the Oligocene clays, but explains that its position in the Tertiary system is not known. Watkins[3] says, "geologically, this area belongs to the Apalachicola group of Oligocene age." The formations in the general region about the sedimentary kaolin occurrences were formerly included in the Apalachicola group of Oligocene age. At present, however, the Alum Bluff formation, formerly considered a part of the Apalachicola group, is regarded as Miocene. This does not necessarily mean that the sedimentary kaolin is of the same age.

Sellards[4] says: "The place of the clay-bearing formation in the geologic time-scale is difficult to determine owing to the complete absence of fossils. It overlies the Oligocene limestones. There is also some reason for believing that it lies at a stratigraphic level higher than the fuller's earth beds and hence is not older than the Miocene. However, inasmuch as no one of the later formations is found overlying this formation, it is not possible to fix its age more definitely."

The fact that the clay formation is found overlying the fuller's earth confirms the belief that it is at least younger than that stage of the Alum Bluff when the fuller's earth was deposited.

ORIGIN

The origin of the sedimentary kaolin has not as yet been satisfactorily explained. The beds are, without doubt, sedimentary, as is indicated by the cross-bedding within the clay-bearing sand; by the fact that the various substances, such as green clay, fuller's earth, limestone, etc., underlie the sand; and by the conglomeratic texture and the presence of water-worn pebbles in the material itself. This formation is apparently everywhere separated from the underlying formations by an unconformity.

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[1]Matson, G. C., The Clays of Florida, U. S. Geol. Survey Bull. 380, p. 353, 1909.

[2]Ries, H., High Grade Clays of the Eastern United States, U. S. Geol. Survey Bull. 708, p. 289, 1922.

[3]Watkins, Joel H., White-Burning Clays of the Southern United States, Trans. A. I. M. E., Vol. 51, p. 481, 1916.

[4]Sellards, E. H., The Clays of Florida, Journal American Ceramic Society, Vol. I, p. 318, 1918.

Moreover the present deposits of this material probably represent remnants of a formerly continuous deposit covering, at least, a large portion of central-peninsular Florida. The presence of quartz and mica indicates that the material was derived from the residual clays of some granitic region, probably upper Georgia. That the ultimate source of the material was to the northward is indicated by the fact that the larger pebbles are found in the northern part of the region as is pointed out by Ries.[1]

Davis[2] in attempting to explain the high plasticity of these clays says that they are probably flood-plain clays and are supposed to have resulted from the transportation and deposition of material from a granite area. In continuing this same line of thought, Watkins[3] says: "It is very probable, however, that this kaolin was first deposited in Cretaceous times and later eroded and transported to its present position. As this portion of Florida is several hundred miles farther from the crystalline area than the Cretaceous horizon, it is reasonable to suppose that the particles of kaolin held in suspension for so great a distance would be more finely divided than those which were deposited in Cretaceous beds. This, to some degree, may account for the fact that the Florida clays are more plastic than the Cretaceous clays."

A different theory was earlier suggested by Sellards[4] when he said: "The admixture of finely divided clay, kaolinitic in nature, with the coarse sands which characterize these deposits, is difficult to account for, except upon the hypothesis that when deposited the formation consisted of coarse quartz and feldspar sands. The quartz being more resistant has remained but little changed, forming the coarse sand of the formation. The feldspar sands, since their deposition, have been subjected to decay, thus forming the kaolinitic clay of the present formation."

This theory encounters serious objections. If climatic and physiographic conditions similar to those of the present are postulated

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[1]Ries, H., The Clays of the United States East of the Mississippi River, U. S. Geol. Survey Prof. Paper No. 11, p. 82, 1903.

[2]Davis, N. B., The Plasticity of Clay and Its Relation to Mode of Origin. Trans. A. I. M. E., Vol. 51, pp. 451-480, 1916.

[3]Watkins, Joel H., White-Burning Clays of the Southern Appalachian States, Trans. A. I. M. E., Vol. 51, pp. 481-501, 1916.

[4]Sellards, E. H., The Soils of Florida, Florida Geol. Survey, Fourth Annual Report, p. 21, 1911.

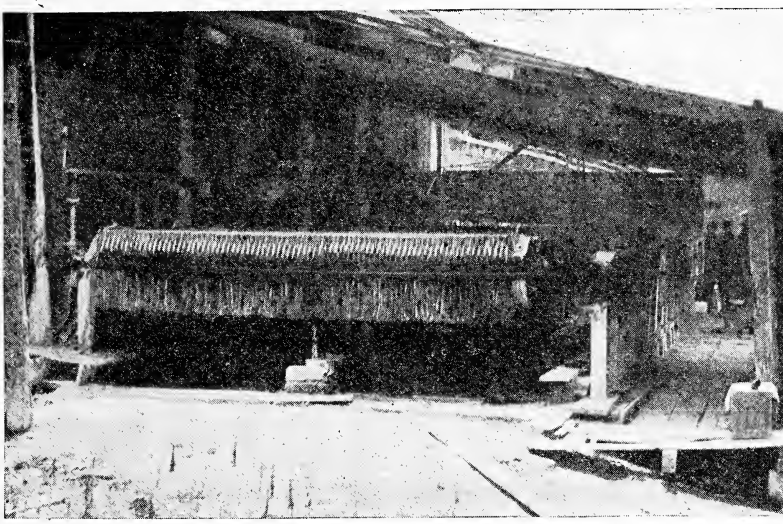

FIG. 41.—Filter presses, Edgar Plastic Kaolin Co., Edgar, Putnam County.

for Florida and the coastal plain regions, as is generally believed to have been the case during Tertiary times, then the feldspar would have become completely decomposed long before it could have been transported from the crystalline area on the north to the sedimentary kaolin region, several hundred miles southward. There is no evidence to indicate that the crystalline areas have within late Tertiary times been at a much greater elevation than at present to facilitate rapid transportation. For this hypothesis to be workable, rapid transportation of the feldspar material would be necessary in order to avoid decomposition before final deposition.

Moreover, under Sellards' hypothesis one would expect to find pebbles or fragments of undecomposed feldspar present in the formation, as well as fragments of only partially altered feldspar. None have so far been reported. The clay would also be present in small lumps instead of the finely divided state in which it is found. In the alteration of feldspar to kaolinite free silica is one of the resulting products. If it is assumed that this silica took the form of quartz then it would be difficult to account for the rounded and water-worn conditions of the quartz grains present. No other form of silica, as opal, is found in or associated with the clay-bearing formation.

Gill[1] suggests that the formation of this clay-bearing sand may have occurred in the following manner: Spring floods carried quartz sand and mica to the peninsular region where it was deposited as cross-bedded sediments in lagoons or other arms of the sea. Then, during the seasons of less rainfall, the streams emptied milky water with the clay substance in suspension into the areas containing the sand. The clay substance was then deposited as a thin coating over relatively thin layers of sand. The lagoons were more or less quiet during the drier seasons, but during the periods of freshets the additional quantities of water caused conflicting currents, which assisted to some extent in reworking the deposits and disseminating the clay substances more thoroughly throughout the sand. Alternate deposition of quartz-sand and milky water with alternating seasons caused the intimate admixture of sand and clay and the accumulation of the present thickness of it.

It is not only possible, but probable, as is suggested by Watkins, that this material was first deposited as Cretaceous sediments near the base of the granitic area, the ultimate source in the Appalachian region, and these beds were later eroded to supply the sediments for the deposits as now known in Florida. As is also pointed out by both Watkins and Davis, this would account for the higher plasticity of the Florida clays than the present Cretaceous clays of Georgia.

Conditions of sedimentation, in which coarse pebbles, varying from three-fourths of an inch to less than a pin-head, could be intimately mixed with mica and finely divided clay, as this material is, and yet be so free from other substances, particularly those exerting a coloring influence, as iron compounds, is at first thought difficult to explain, especially in view of the fact that the deposits are distributed over a relatively large area. Rettger,[2] however, points out that the deposition of this material is not necessarily very different from any other sandstone. The clay-bearing sand is an unconsolidated sandstone in which the clay content ranges from twenty to forty per cent. Many sandstones have a similarly high clay content.

If shoreline conditions similar to those of the present are postulated for Florida during the time when this formation was being deposited, which was probably Pliocene, with large arms of the sea, relatively shal-

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[1]Gill, A. C., Oral Communication.
[2]Rettger, R. E., Oral Communication.

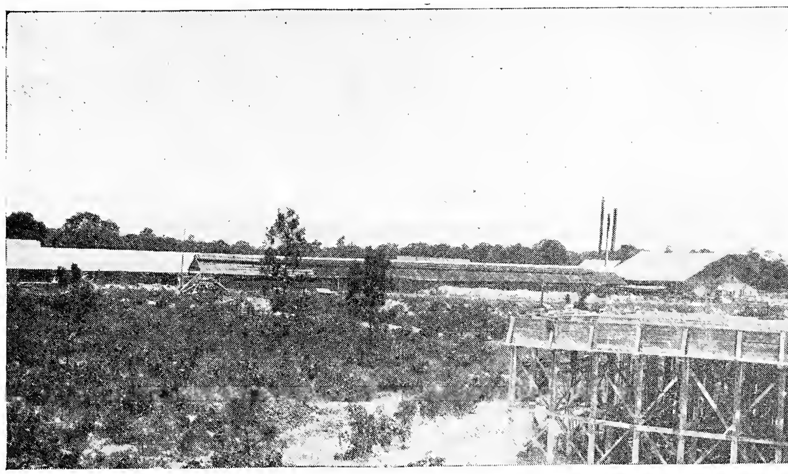

FIG. 42.—Plant of Florida China Clay Co., near Okahumpka, Lake County.

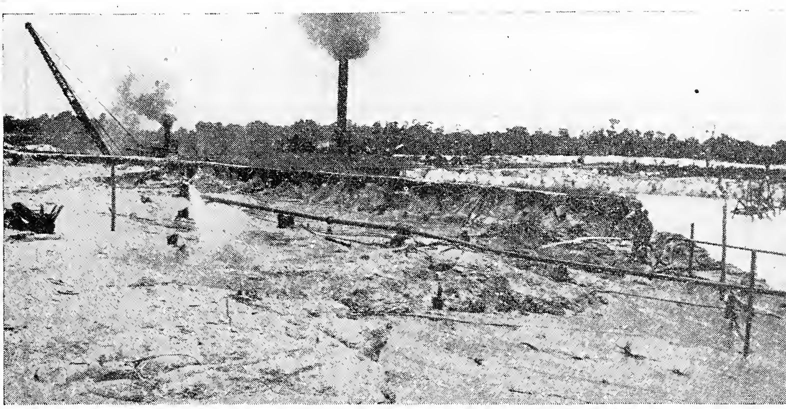

FIG. 43.—Removal of overburden by hydraulicking. Florida China Clay Company, Lake County.

low and more or less connected and largely land-locked, as is now illustrated by the numerous bays and sounds indenting the Florida coastline, then it is easy to conceive of a more or less continuous deposit of this sedimentary kaolin being formed around the border of the peninsula as it existed at that time. This formation has since been largely re-

moved by erosion, so that the deposits known at present are merely remnants.

In this connection it is to be noted that the white Cretaceous clays of Georgia and South Carolina are relatively free from sand and pebbles, and, with one or two exceptions, may be used without first being washed. Their properties are similar to the sedimentary kaolin of Florida, except that the Florida clay has higher plasticity.

The immediate source of the material, i. e., clay and sand, composing the deposits in Florida, is not easy to explain. If it is assumed that the clay was derived from the white Cretaceous clays of Georgia, then another source for the quartz-sand must be sought and its mixture with the clay accounted for.

The source of the Florida sedimentary kaolin, its transportation, geologic age, relation to other sediments, terrestrial and shore-line conditions, distribution and deposition, are problems as yet far from being solved.

HISTORY AND DEVELOPMENT

The Florida sedimentary kaolin was discovered in 1890[1] in mining phosphates, and samples were sent to Mr. C. S. Edgar at Trenton, N. J. As early as 1875, Mr. Edgar had heard rumors of kaolin deposits in Florida, but, upon going there, was unable to find any. In 1892, Mr. Edgar began mining this clay at Edgar under the name of the Edgar Plastic Kaolin Company. This company is still operating at that place. In 1900 the International Kaolin Company began mining clay in the same formation at Okahumpka. There are at present three companies working deposits of sedimentary kaolin: The Edgar Plastic Kaolin Company, at Edgar, in Putnam County; The Lake County Clay Company, and the Florida China Clay Company, both near Okahumpka, in Lake County.

PROPERTIES

The sedimentary kaolin in its crude form consists of sixty to seventy-five per cent quartz-sand and twenty-five to forty per cent clay. The average is probably about sixty-five per cent sand. This natural mixture is washed, thus separating the clay from the sand, and a part, at least, of the mica. The washed product, however, probably does not represent

[1]Ries, H., and Leighton, H., History of the Clay Working Industry in the United States, p. 78, 1909.

much over fifteen per cent of the material excavated. A slight amount of a very fine sand and some mica remains in the washed clay, but the quantity is not sufficient to injure its usefulness, except for some grades of paper-clay.

The washed product at each of the three plants engaged in mining this clay varies little in its properties and uses. It is very plastic, white-burning, refractory, and has medium transverse and bonding strength.

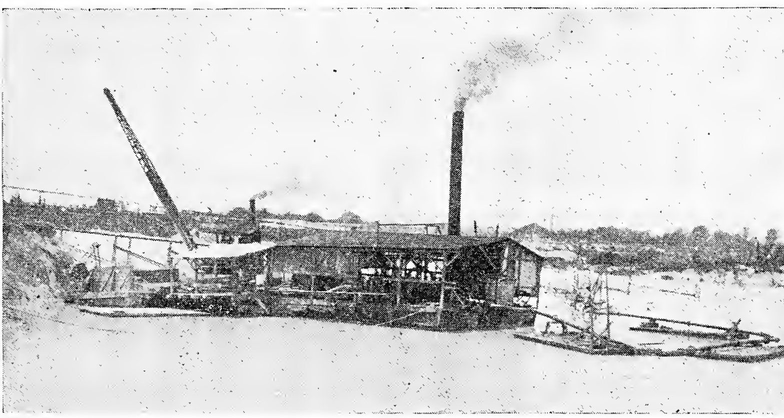

Fig. 44.—View of dredge boat used in mining sedimentary kaolin, Florida China Clay Co., near Okahumpka, Lake County.

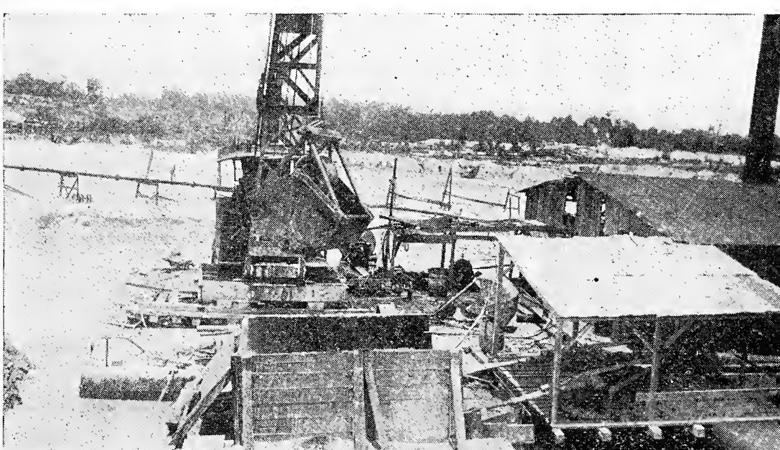

Fig. 45.—Near view of dipper on dredge boat. Refuse sand in background. Florida China Clay Company, Okahumpka, Lake County.

It is not, however, a typical bond clay. It cannot be used alone, as it has a high shrinkage and develops small cracks in firing.

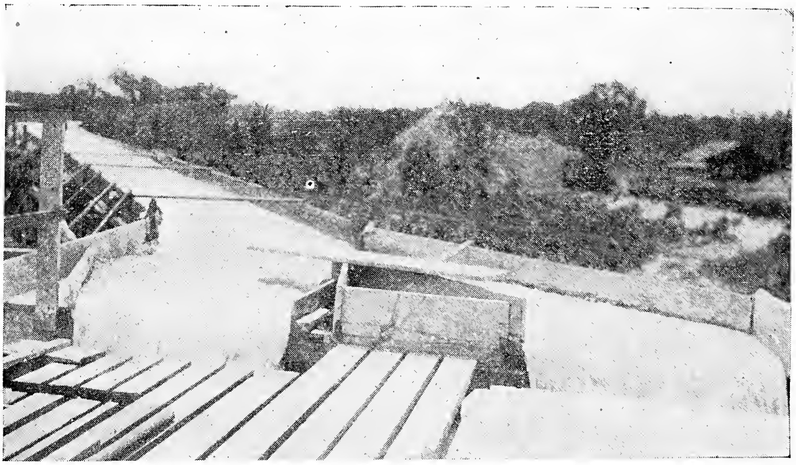

FIG. 46.—Entrance to sand traps, Florida China Clay Co., Okahumpka, Lake County.

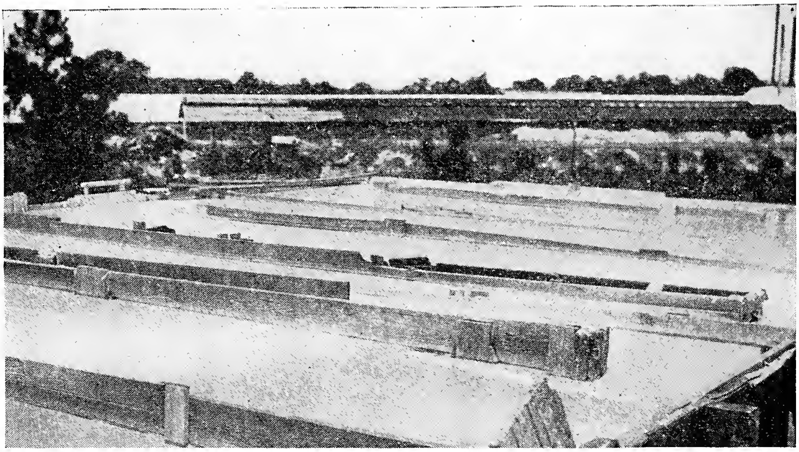

FIG. 47.—Settling troughs, Florida China Clay Co., Okahumpka, Lake County.

A sample of the washed clay from the Edgar Plastic Kaolin Company's Plant at Edgar had the following physical properties:

Physical Properties of Edgar Plastic Kaolin (Lab. No. o-57).

Plasticity, judged by feel...........	Excellent.
Water of plasticity.................	34.65%
Pore water	0.21%
Shrinkage water	34.44%
Linear air shrinkage...............	10.0 %
Volume air shrinkage..............	27.5 %
Modulus of rupture, average........	169.1 pounds per square inch.
Slaking test	5 minutes.
Steel hard at cone 1.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	5.0	29.49	45.75	White.
1050	5.2	29.46	46.60	White.
1150	6.0	20.32	37.80	White.
1190	7.5	21.45	37.60	White.
1230	12.0	13.06	27.50	White.
1310	12.0	14.30	30.20	White.
1370	12.5		16.80	White.
1430	13.0	7.07		White.

A sample of the washed clay from the Lake County Clay Company's plant, near Okahumpka, had the following physical properties:

Physical Properties of Lake County Clay Company Sedimentary Kaolin (Lab. No. o-84).

Plasticity, judged by feel...........	Excellent.
Water of plasticity.................	31.85%
Pore water	0.42%
Shrinkage water	31.43%
Linear air shrinkage...............	8.0 %
Volume air shrinkage..............	22.0 %
Modulus of rupture, average........	136.3 pounds per square inch.
Slaking test	3 minutes.
Steel hard at cone 3.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	3.5	34.61	49.50	White.
1050	4.5	30.79	47.20	White.
1150	5.4	23.62	41.20	White.
1190	10.0	23.60	34.75	White.
1230	10.0	16.09	33.50	White.
1310	14.5	14.74	30.75	White.
1370	17.0	6.38	16.42	White.
1430	18.0	5.14	12.40	White.

A sample of the washed clay from the Florida China-Clay Corporation's plant, near Okahumpka, had the following physical properties:

Physical Properties of the Florida China Clay Corporation's Sedimentary Kaolin (Lab. No. o-83).

Plasticity, judged by feel	Excellent.
Water of plasticity	34.65%
Pore water	0.59%
Shrinkage water	34.56%
Linear air shrinkage	9.5 %
Volume air shrinkage	25.8 %
Modulus of rupture, average	201.0 pounds per square inch.
Slaking test	3 minutes.
Steel hard at cone 1.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
950°C.	4.5	34.16	42.20	White.
1050	5.5	27.08	45.75	White.
1150	6.5	16.12	32.50	White.
1190	12.5	6.78	16.10	White.
1230	13.5	4.94	12.30	White.
1310	15.5	4.86	12.60	White.
1370	16.0	1.60	6.65	White.
1430	17.5	1.37	4.38	Light gray.

A sample of the washed clay from one of the mines near Okahumpka was tested in the laboratory of the Bureau of Mines[1] at Columbus, Ohio. It had the following physical properties:

General Physical Tests of Washed Clay from Okahumpka.

Workability	Very plastic; molds well.
Water of plasticity	49.78%
Volume air shrinkage	32.15%
Linear air shrinkage, calculated	12.20%
Modulus of rupture, average	181.00 pounds per square inch.
Deformation temperature, cone 31 plus.	
Steel hard at cone 3.	
Develops small cracks in firing.	

Fire tests:

Temperature.	*Linear Shr. Per Cent.*	*Absorption. Per Cent.*	*Porosity. Per Cent.*	*Color.*
190°C.	12.1	32.10	28.30	White.
1250	12.5	38.11	27.05	Faint cream white.
1310	14.4	37.33	23.41	Faint cream white.
1370	18.7	46.30	7.40	Cream.
1410	20.3	49.40	2.20	Buff.

[1]High Grade Clays of the Eastern United States, U. S. Geol. Survey Bull. No. 708, p. 291, 1922.

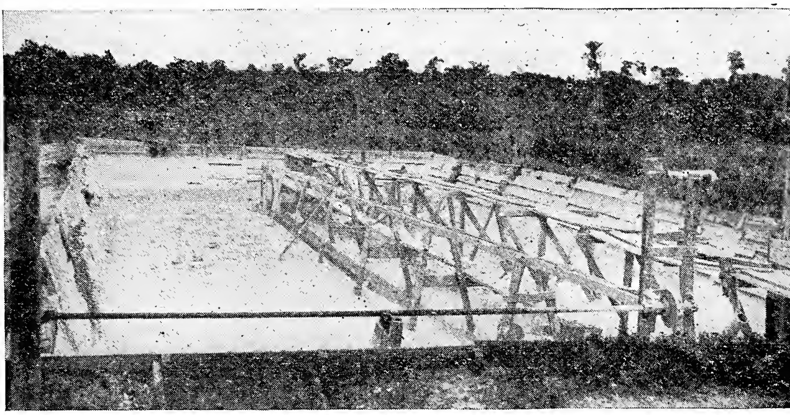

Fig. 48.—Settling vat, Florida China Clay Company, Okahumpka, Lake County.

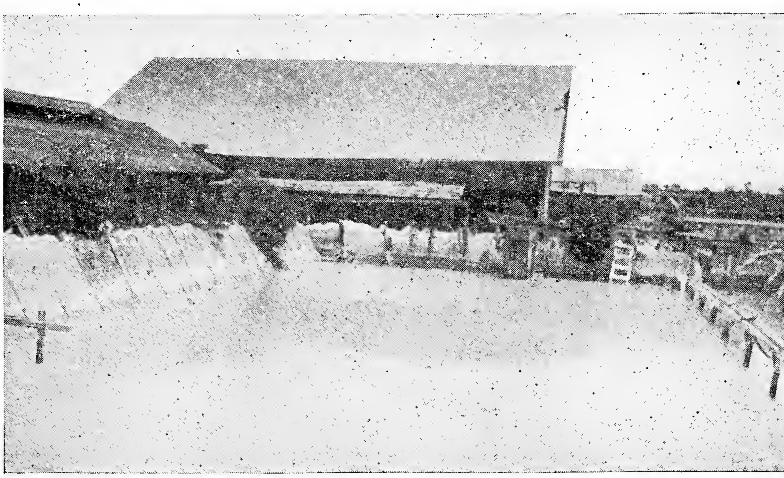

Fig. 49.—Settling vat partially filled, Florida China Clay Company, Okahumpka, Lake County.

The following analyses of the sedimentary kaolin indicate its chemical properties:

Chemical Analysis of Washed Clay from Palatlakaha River.[1]

Silica (SiO_2)	46.11
Alumina (Al_2O_3)	39.50
Ferric Oxide (Fe_2O_3)	0.35
Magnesia (MgO)	0.13
Water (H_2O)	13.78
Sulphur Trioxide	0.07
Total	99.94

[1]U. S. Geol. Survey Seventeenth Annual Report. Part III Cont'd, p. 837, 1896.

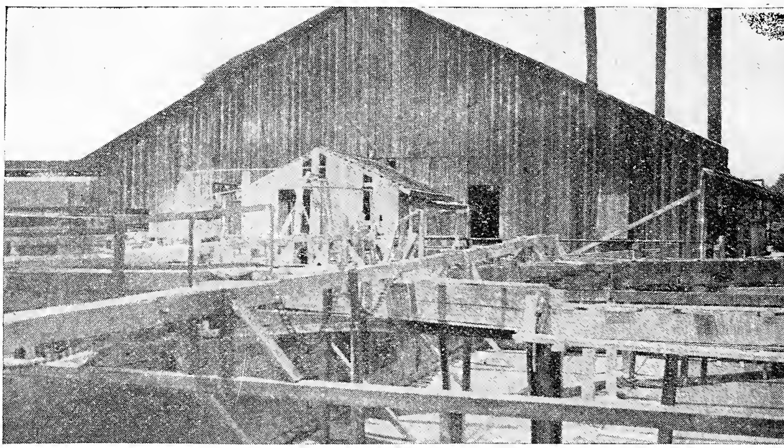

FIG. 50.—Empty settling vat. Florida China Clay Company, Okahumpka, Lake County.

Chemical Analysis of Washed Clay from Edgar. C. Langenbeck, Analyst.[1]

Silica (SiO_2)	45.39
Alumina (Al_2O_3)	39.19
Ferric Oxide (Fe_2O_3)	0.45
Lime (CaO)	0.51
Magnesia (MgO)	0.29
Alkalies (Na_2O, K_2O)	0.83
Water (H_2O)	14.01
Total	100.67

MINERALOGY

Somers[2] studied samples of the Florida sedimentary kaolins microscopically and found kaolinite to be abundant, hydromica, fairly abundant; and a few grains of rutile, chlorite, and zircon to be present. He reports that sillimanite was developed in one of the test pieces fired at 1150° C. where the conditions happened to be favorable for its development. He believes it to have been formed from the large flakes of kaolinite or low-grade hydromica.

USES

The Florida sedimentary kaolin is used almost exclusively in the white-ware industries. Its principal uses are in making pottery, decorative tile, spark plugs, and electric porcelain.

[1]Chemistry of Pottery, p. 100.

[2]Somers, R. E., Microscopic Study of Clays included in U. S. Geol. Survey, Bull. 708, p. 292, 1922.

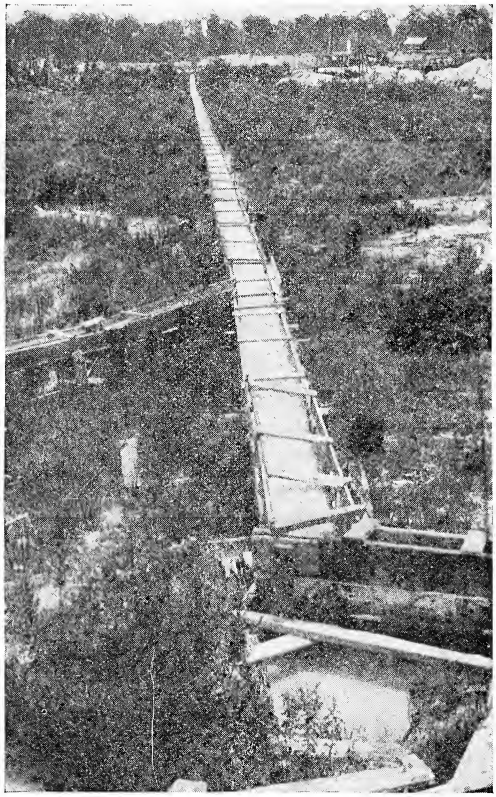

FIG. 51.—Sluice for returning water from filter presses to clay pit. Florida China Clay Company, Okahumpka, Lake County.

The greater part of the output is shipped to the pottery centers in New Jersey, New York, Ohio, and Pennsylvania. Shipments are also made to other eastern states, to some of the Mississippi Valley states, and to the Pacific Coast states.

One of the small potteries in Florida was experimenting with mixtures of the sedimentary kaolin and other clays during the summer of 1922. The results at that time were satisfactory.

METHODS OF MINING

The overburden is removed at Edgar and at the Lake County Clay Company's plant, near Okahumpka, by a steam shovel. At the Florida

China Clay Corporation's plant, also near Okahumpka, the overburden is removed by hydraulic process.

The method of mining this clay is very different from any commonly employed in clay-mining. Owing to the slight topographic relief of the region and the proximity of the ground water-table to the surface, ordinary open-cut methods would be unsuccessful, and consequently dredging is resorted to. After the overburden is removed, a pit is dug into the deposit of sand-bearing clay in which, after it is filled with water, a dredge is floated. The clay is then dug by dredging and forced through a pipe to a series of three "sand traps," where the greater part of the sand is eliminated. The clay-bearing water then passes through a series of troughs, where it is continuously agitated, to cause the clay substance to remain in suspension and the impurities, which usually have a higher specific gravity, to settle out. From this troughing the clay-bearing water passes into settling vats and the water is later pumped off. The clay is then forced through filter-presses, where the excess water is pressed out. The resulting cakes of damp clay are dried in either steam or air-heated drying sheds, and, when dry, are ready for shipment. From the time the clay is first dredged until it leaves the filter presses, all water extracted from it, and which necessarily carries some clay, is conducted back to the pit. Some clay is lost, however, in the sand-traps and is carried out with the waste sand.

The sand washed from the clay is used to some extent in concrete construction. It has been suggested that this sand could be used for glass manufacture, but so far as is known, no practical tests have been made to determine its suitability for this usage.

DISTRIBUTION BY COUNTIES

Occurrences of sedimentary kaolin have been noted or reported in the following counties:

Alachua County—A well drilled at the gin in Hawthorne, near the eastern border of the county, is reported by W. S. Moore, of that place, to have encountered the clay-bearing sand at a depth of twelve feet. The thickness of the deposit it not known. This place is located only about eight miles west of Edgar. As occurrences of the sedimentary kaolin are known west and southwest of Edgar, similar deposits in the adjoining portions of Alachua County are not at all improbable.

Sedimentary kaolin also occurs two miles south of Fairbanks, on Hatchett Creek. The overburden here is less than two feet. The thickness and extent of the deposit and its relation to a nearby gray clay was not determined.

Citrus, Clay and DeSoto Counties—Sedimentary kaolin has been reported to occur four miles east of Inverness, and seven miles west of Floral City, in Citrus County, in the region about Brooklyn and Lake Geneva, in Clay County, and in the vicinity of Arcadia, in De Soto County. These occurrences, however, were not verified.

Hernando County—Sedimentary kaolin was noted eight miles south of Brooksville on the Brooksville-Dade City road. The deposit here is approximately twenty feet thick and is underlain by a bluish-gray jointed clay. The overburden is less than three feet.

This formation is also exposed in an abandoned phosphate mine, ten miles east of Brooksville and three miles west of Rital. Here there is three feet of sand as overburden and twenty feet of the clay-bearing sand exposed. Water in the bottom of the pit concealed the lower part of the formation, so its exact thickness is unknown. The relation of the sedimentary kaolin to the hard-rock phosphate was not worked out in detail.

Highlands County—Sellards and Gunter[1] report "kaolin" in this county, but do not give specific locations. Sedimentary kaolin is no doubt the material referred to. As stratigraphic and physiographic conditions are essentially identical with those in Polk, Lake, and Putnam counties, it is not at all improbable that occurrences of this material should be found in Highlands County.

Lake County—Lake County is one of the principal producers of sedimentary kaolin in Florida. Numerous deposits are known in the south-central part of the county, south of Lake Harris, and along the Palatlakaha River for a distance of ten or twelve miles.

Two plants are actively engaged in mining this material about two miles east of Okahumpka, near the junction of the Palatlakaha River and Lake Harris. One of these is the Florida China Clay Corporation and the other is the Lake County Clay Company. The plants are about one mile apart and both are located on spurs of the Atlantic Coast Line.

[1]Sellards, E. H., and Gunter, Herman, Petroleum Possibilities of Florida, Florida Geol. Survey Fourteenth Annual Report, p. 107, 1922.

The Florida China Clay Corporation's mine was formerly known as the Old Richmond Mine, and is located in Sec. 12, T. 20 S., R. 24 E.

The Lake County Clay Company's plant is located in Sec. 13, T. 20 S., R. 24 E. It is operated by the same company that owns and operates the plant at Edgar in Putnam County. The mine was formerly known as the Florida Clay Company Mine and has been in operation about thirty years.

The clay in this general region occurs in deposits of irregular thickness and outline and are separated by partitions of yellowish sand, probably old erosion channels, which run in various directions. Numerous exposures of the clay-bearing sand may be seen along the Palatlakaha River and on the south shore of Lake Harris.

The following typical sections indicate the range in thickness of overburden, clay and the material beneath the clay-bearing formation. These sections are taken from records of borings on the property of the two companies operating here:

Sedimentary Kaolin Sections, near Okahumpka.

		Feet.
1.	Sand, yellowish (overburden)	6
	Clay, red, sandy	3
	Sedimentary kaolin sand	30
	Blue clay	?
2.	Sand, surface	11
	Sedimentary kaolin sand	27
	Limestone	?
3.	Sand, surface	10
	Sedimentary kaolin sand	30
	Flint	?
4.	Sand, surface	6
	Sedimentary kaolin sand	25
	Marl	?
5.	Sand, surface	4
	Sedimentary kaolin sand	14
6.	Sand, surface	6
	Sedimentary kaolin sand	19
	Green clay	?

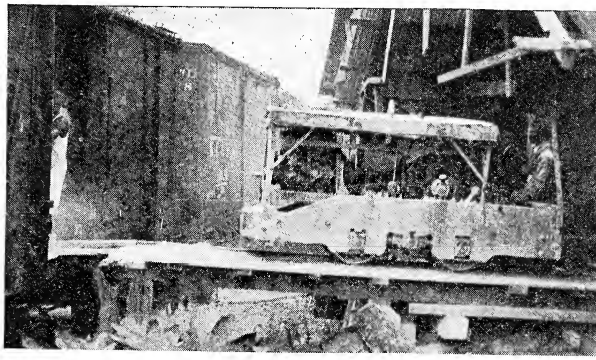

FIG. 52.—Motor used in loading cars. Florida China Clay Company, Okahumpka, Lake County.

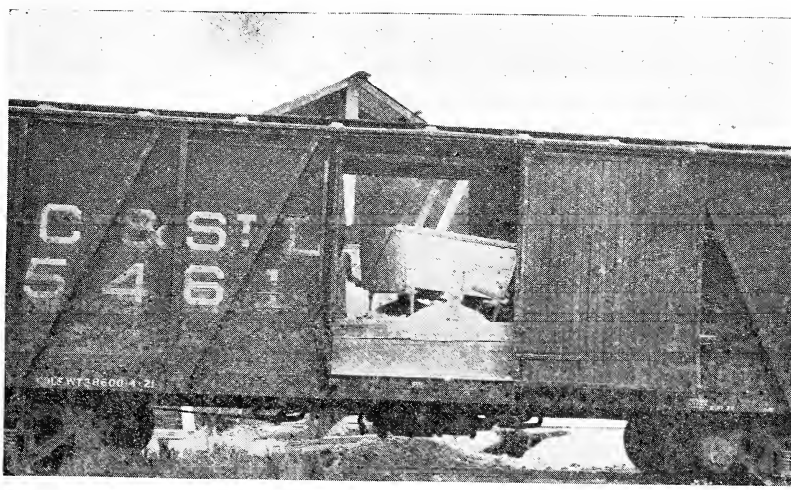

FIG. 53.—Loading cars. Florida China Clay Company, Okahumpka, Lake County.

As may be seen from these sections, the materials underlying the sedimentary kaolin are variable. Fuller's earth was encountered in some of the borings. The maximum thickness of clay-bearing sand found in this region was 32 feet.

Sedimentary kaolin is exposed on the south side of Lake Harris, on the property of R. F. Kleiser, in Sec. 22, T. 20 S., R. 25 E. A.

four-foot exposure of the clay-bearing sand may be seen above the level of the lake. The overburden is three feet of soil and the clay is thirty feet in thickness. This deposit is three miles east of the Lake County Clay Company's plant and one-half mile east of Yalaha.

Levy County—An occurrence of sedimentary kaolin was noted in a road-clay pit in the northwest part of Bronson, about two hundred yards north of the Seaboard Air Line Railway station. About six feet of the clay-bearing formation was exposed, but the depth and extent of the deposit was not determined. The overburden was about three feet.

Marion County—Occurrences of sedimentary kaolin have been found in both the extreme southeast corner of the county and in an area in the northwestern quarter of the county.

A water well, dug on the property of Captain E. E. Greer, Sec. 32, T. 17 S., R. 26 E., in the southeastern part of the county, went through twelve feet of soil and surface sand, then through thirteen feet of sedimentary kaolin. The well stopped in the clay-bearing sand, hence its thickness is not known.

Another deposit, also in Sec. 32, T. 17 S., R. 26 E., was found on the property of Harry L. Collins, about three-quarters of a mile northwest of the Greer occurrences. The overburden here consisted of five feet of loose surface sand and seven feet of red sandy clay (sand-clay road material). Ten feet of the clay-bearing sand was exposed immediately below the red sandy clay. Its exact thickness and extent was not determined.

In the extreme southeast corner of the county and extending into Lake County, near Altoona, is another deposit in which fifteen feet of the clay-bearing sand is exposed. It is overlain by five feet of sand. The thickness and extent of the clay formation was not determined. This deposit has been worked for road material and contains more numerous coarse gravel, or conglomeratic layers, than the average.

Occurrences of the clay-bearing formation was noted in the northwestern part of the county near Friendship School, ten miles northwest of Ocala, and in two exposures three miles northwest of Emathla, on the Tampa and Jacksonville Railroad. The thickness and extent of these deposits was not determined.

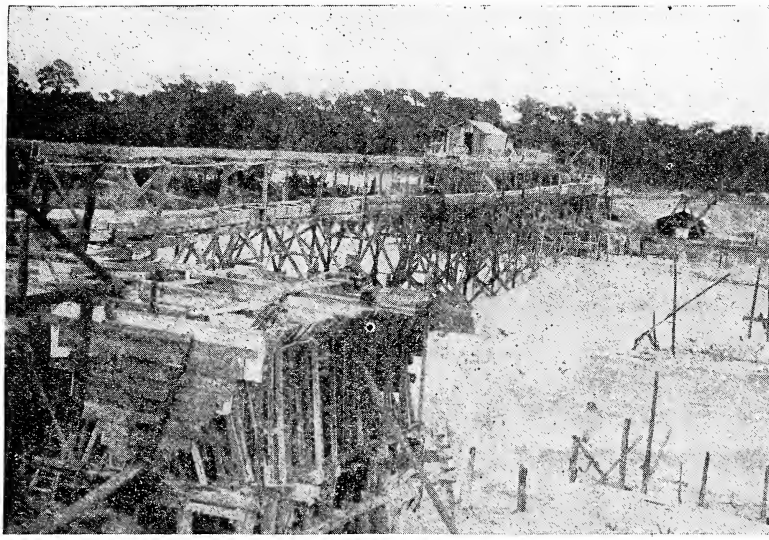

FIG. 54.—Dredge Boat (in left background), sluiceways and sand traps (foreground). Lake County Clay Company, Okahumpka, Lake County.

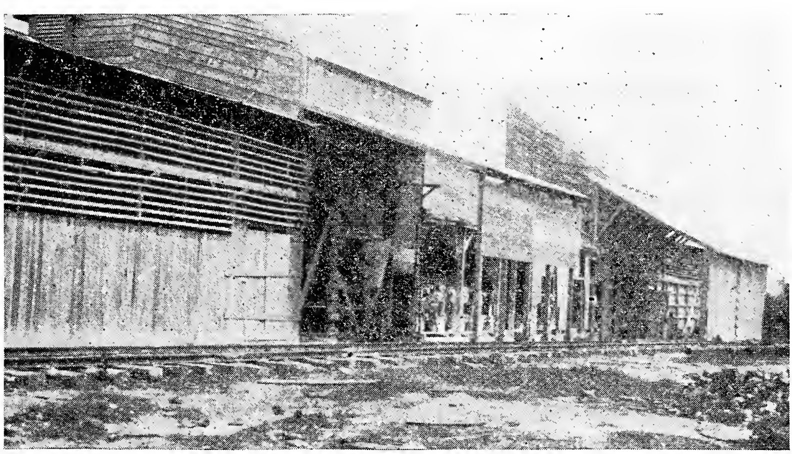

FIG. 55.—General view of drying sheds, warehouses and loading docks. Lake County Clay Company, Okahumpka, Lake County.

A six-foot stratum of the sedimentary kaolin-bearing sand, overlain by three feet of soil, is exposed in a well at the home of B. S. Quarterman, Sec. 34, T. 13 S., R. 20 W. The clay formation is underlain by fuller's earth, which is reported to be twenty-three feet in thickness.

Pasco County—Exposures of the sedimentary kaolin sand were noted around the south border of Mirror Lake, a few miles northwest of Dade City. The thickness and extent of this deposit was not determined.

The plastic kaolin also appears on the property of Jas. Lampson, one-half mile east of the Atlantic Coast Line Railroad and three miles southeast of Dade City. This deposit is overlain by about three feet of soil. The extent of this deposit is reported to be more than ten acres.

Another occurrence of this clay is on the property of J. H. Klocker, one mile northwest of San Antonio, in Sec. 34, T. 24 S., R. 20 E. A boring indicated three feet of surface sand, six feet of red-clay sand, and three feet plus of the white clay-bearing sand. The full thickness and extent of this deposit was not determined.

Polk County—The sedimentary kaolin occurs in numerous places in Polk County in the vicinity of Bartow Junction (Lake Alfred) and Winter Haven.

Putnam County—This county is one of the principal producers of sedimentary kaolin in Florida, as shown on preceding pages. Numerous occurrences are known in the region about Edgar, Johnson and McMeekin.

The Edgar Plastic Kaolin Company operates one mine at Edgar. A generalized section at this locality is:

Overburden	6 to 20 feet
Clay-bearing sand	15 to 30 feet

The clay is underlain in places by a red-streaked clay, two feet in thickness, in places by a limestone and in other places by a green clay. Fuller's earth is reported to underlie the green clay in places.

The Foster Kaolin Company's mine, now abandoned, is located at Johnson. Here the overburden ranges from twelve to twenty feet, and the clay formation is approximately thirty feet in thickness.

Sedimentary kaolin has also been found on the Monroe property in Sec. 32, T. 10 S., R. 23 E. This is only a short distance southeast of McMeekin and southwest of Johnson.

Suwannee County—Sedimentary kaolin has been reported in the vicinity of Houston and also southwest of Live Oak, but these occurrences were not confirmed.

Walton County—The white clay-bearing sand mentioned on page 213, is in Walton County, five miles south of DeFuniak Springs in Sec. 26, T. 2 N., R. 19 W., on the property of G. P. Billups. This deposit occurs in a small gully washed into an old field near a small stream. The material contains more mica and larger quartzose pebbles than the occurrences of typical sedimentary kaolin, and it is not definitely known that this material is the same.

CHAPTER X

DEVELOPMENT AND POSSIBILITIES OF THE CLAY INDUSTRY IN FLORIDA

EARLY HISTORY

Common building bricks have been produced in Florida since the early days of its history. Ruins of the old English and Spanish settlements in the vicinity of Pensacola indicate that brick were used to a large extent in the construction of dams, foundations, fireplaces, etc., in the eighteenth century. The very earliest enduring structures, both at St. Augustine and at Pensacola[1] were of stone, but later buildings were of brick. While it is not known that these brick were made from local clays, it is curious to note that brick plants are now operated in close proximity to some of these old Spanish and English landmarks and that clay suitable for common brick is found underlying many of them. It seems improbable that the brick used here would have been imported. The exact date when brick were first used is not recorded. In 1766, clay from Pensacola was shipped to Josiah Wedgewood's pottery in England, for experimental purposes[2]. Williams, writing in 1827, states that both brick and fire-brick were manufactured in West Florida and shipped to New Orleans.[3]

During the nineteenth century, both before and after the Civil War, the Anglo-Saxon settlers, then blazing the trail for the permanent settlement of the Florida of today, operated small brick-yards to supply their immediate needs. Many of these crude plants, which are now abandoned, may be found throughout the central, northern and western portions of the State. Fort Jefferson, on the Dry Tortugas, in the Gulf of Mexico, was built in 1860 of brick made on Escambia Bay.[4]

RECENT HISTORY

In the last three or four decades, eighteen or twenty plants, manufacturing structural materials, have been in operation more or less continuously, and during this time the rank of Florida, as determined by

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[1]Gonzalez, Mrs. S. J., Pensacola, Its Early History, Quarterly of the Florida Historical Society, p. 10, April, 1909.

[2]Meteyard, Eliza, Life of Josiah Wedgewood, Vol. I, p. 471, 1865.

[3]Williams, John Lee, A View of West Florida, p. 69, 1827.

[4]Crary, J. W., Sr., Brickmaking and Burning, pp. 14 and 35, 1890.

the value of its clay products, has ranged between thirty-seventh and fortieth as a brick-producing State. Common brick has been by far the greatest item of production, but hollow block, drain tile and face brick have also been produced to some extent.

The development of the common-brick industry has made relatively little progress within the past thirty or forty years and has fallen far short of keeping pace with the constantly growing demand for structural materials. The reasons for this condition are varied, and will be treated in subsequent paragraphs.

PRESENT STATUS

Seventeen plants are engaged at present in the production of common brick. Two of these plants are located in the northeastern part of the State, four in the north-central part of the peninsula, and the remaining eleven are situated in west Florida. That portion of the State which has the greatest demand for common brick and other structural materials has only about one-third of the producers within reach.

Five of the common-brick producers also manufacture face brick, two of them also produce hollow block, and one manufacturer produces drain tile. For these higher-grade products more thorough preparation of the raw clay is made and more careful treatment during the process of manufacture is accorded it. In each case, however, the same raw materials are used as for the common brick.

No stoneware is now being produced in Florida. A pottery manufacturing jugs, jars, crocks, and similar articles, was formerly operated at Pensacola. One brick plant, Barrineau Bros., at Quintette, is equipped for the manufacture of turpentine cups.

Three small potteries are being operated in the State and these are engaged chiefly in the production of ornamental articles, such as candlesticks, vases, urns, jardinieres, book-ends, and the like. These pieces are often made of clays of several different shades, so as to bring out a pleasing contrast of colors. Such wares are commonly not glazed and are burned only sufficiently hard to enable them to withstand ordinary handling. Vitrification is never reached. Some of the products of these potteries are made of blends of several clays which are thoroughly mixed and to which a glaze is frequently applied. Many of the pieces, both those made from natural clays and those made from

pottery mixtures, or blends, are, after firing, painted and decorated by hand. Clay products of this type find a ready local market among the tourists in the winter resorts of the State.

The Orlando Pottery is located two miles northwest of Orlando on the Apopka Road. This company, which has been organized only about two years, is equipped to carry on an extensive trade in ornamental pottery, curios, etc. The operation up to this time may be regarded as largely experimental in determining the best biscuit and glaze formulæ as well as the most satisfactory treatment to be accorded the materials and the most expeditious methods of handling the wares. The materials are washed, mixed and tempered by hand and molding is done by throwing and by casting. Burning is done in one large circular up-draft kiln and two small down-draft kilns. From fifteen to twenty persons, including the decorators, are employed. Some of the ware is placed on the market in an unglazed condition and the remainder is glazed and then decorated by hand. Most of the output is sold in Orlando, but shipments are also made to south and east Florida.

Feldspar and flint are shipped in from northern markets, and, in the past, clays from other states have been used. Some local clays, however, have since been found which give satisfactory results in certain blends and these have displaced the northern clays to some extent. The Florida sedimentary kaolin has been successfully tried in some of the mixtures. Saggers are purchased from northern firms and wad-clay is also procured in the North. Seger cones are used to indicate the progress of firing, which is ordinarily completed at cone 06.

The Florida Pottery, located at 2430 Euclid Avenue, St. Petersburg, produces the "Kohler Ware", marketed in numerous places in south Florida. This consists of vases, jars, etc., in attractive designs and decorations prepared primarily for tourist trade. As many as four or five clays are at times used in such a way as to give the ware a streaked appearance. These clays are of different colors and are not intimately mixed as a blend but are used as small stringers so that a series of colors show in the finished products. A glaze is applied to the interior of the ware. The clays are washed and tempered by hand. Molding is done entirely by throwing on a potter's wheel.

The H. A. Graack & Son Art Pottery, located in Bradentown, uses chiefly a clay dredged from the Manatee River, which is first allowed to weather for a time, then washed and prepared by hand. Mold-

ing is done by throwing. No blends are used. The product, which is sold locally, includes hand-decorated vases, candle-sticks, curios, etc. The ware is burned in a small up-draft kiln.

With the exception of the sedimentary kaolin and the fuller's earth, no raw clays are mined in Florida for shipment to points outside the State. For a discussion of the sedimentary kaolin, see Chapter IX.

PRESENT TENDENCIES

General Development and Expansion in Florida—The growth and development of the industries of Florida during the past few years has been phenomenal. This expansion is perceptible in every industry in the State and is closely related to the general development and improvement which has been taking place in all the Southern States. The magnitude of Florida's industries may be determined from the following table of production in the year 1920:

Agriculture	$150,139,749.00
Minerals	20,000,000.00
Forest Products	25,000,000.00
Fisheries	20,000,000.00
Manufacturing	150,000,000.00

Of these industries, agricultural, including horticultural pursuits, are of chief importance, and are the ones most likely to continue to expand. Of 35,111,040 acres of land in the State and of which, it is claimed, approximately 85 per cent is capable of cultivation, only 17.2 per cent is now in farms and only 6.5 per cent is classed as improved land. Not all of this is actually cultivated.

The mineral production consists chiefly of phosphates, fuller's earth, lime and sedimentary kaolin, with a few other products playing a minor part. The mineral industry of the State is not likely to greatly increase, unless now unknown products are discovered, but will probably remain at about the same point for some time in the future as in the past ten years.

While Florida is not regarded as a manufacturing State, the value of its manufactured products at present equals the value of the agricultural products. The manufacturing industries in the State are capable of, and likely to be, greatly increased in the coming years. There is a decided tendency for many manufacturing concerns to move to

the Southern States, where a more favorable climate and lower living costs prevail.

Parts of Florida have become widely known as winter resorts. This is particularly true of the Atlantic coast, the southern two-thirds of the peninsula, and the Gulf coast. This has given rise in the tourist centers to a development peculiarly adapted to the needs of winter visitors, and has called for an extraordinary amount of building in this part of the State.

In 1921, there were 5,312 miles of railway within the State, which amply serves the regions already developed, and in which development will continue for some time. Water transportation is also highly developed and is carried on inland by rivers, lakes and canals. Interstate and foreign marine commerce is an item of considerable magnitude, which is handled through three chief ports (Jacksonville, Tampa, and Pensacola) and numerous smaller ones.

SOURCES OF STRUCTURAL MATERIALS

Within the last half-century the production of common brick and tile in Florida has not supplied the demand for these materials. Georgia and Alabama producers have been called on to supply the shortage, which has resulted in Florida becoming one of the principal markets for the products from these states. The excessive increase in freight rates, in addition to the enormous development in south Florida, has, within the last decade, caused an earnest inquiry into the possibilities of developing a local supply of structural materials adequate to meet this growing demand or for finding satisfactory substitutes.

The three producers in the extreme western portion of the State (Escambia County) have, on the other hand, marketed much of their output in neighboring states, even supplying wants as far away as New Orleans. It is to be noted, however, that the shipping distance by rail from Pensacola to South Florida is greater than from the Piedmont section of Georgia, thus making it cheaper to use Georgia products than those from West Florida. Shipment by water from Pensacola would mean hauling the brick several additional times, thus making it little, if any, cheaper than rail transportation. It is most expedient, therefore, for Georgia brick to be used in peninsular Florida, when local supplies are inadequate or of unsuitable quality, in preference to

the products from western Florida; and on the other hand, the Escambia County producers can best dispose of their wares in West Florida and adjoining portions of Alabama and Mississippi.

Paving brick, the highest grades of face brick and sewer pipe are not produced in Florida, and, so far as is known at the present time, there are no clays within the State adapted to the manufacture of these products. Face brick of good quality can be produced in many places, but the best grades, suited for certain types of work, cannot be satisfactorily produced. For paving brick, sewer-pipe, and certain grades of face brick, therefore, Florida will be dependent upon outside supplies.

SUBSTITUTES FOR CLAY PRODUCTS

Numerous substitutes for clay-building products have been used with varying degrees of success and, without doubt, some of them will continue to be extensively used.

Reinforced concrete, for example, has proved very satisfactory in Florida as in practically all of the other states, and much of the structural work of the future will be of this material. At present, Portland cement is not produced in Florida, and again Georgia and Alabama products, or those from other states, must be imported with very high freight rates to supply local needs; moreover, clean, sharp sand and gravel for concrete work is difficult to obtain in south Florida, where the greatest construction work is being carried on.

The lime industry in Florida is an important one and has given rise to the production of sand-lime brick. These are artificial brick, made of sand and quicklime. Florida ranks third in the manufacture of sand-lime brick. These brick have the same dimensions as common brick, and are used in structural work in the same manner. The use of sand-lime brick has proven successful, and will doubtless continue to be a common substitute for brick.

Florida has no good building stone. Some of the soft limestones in west Florida and the coquina rock as well as the oolitic limestone occurring along the east coast, have been successfully used to some extent for structural materials.

An artificial building stone, particularly for ornamental work, columns, arches, keystones, sills, etc., is made of crushed Ocala limestone, coquina, or loose shells, with sand and lime. This makes a very

attractive product and is used in lieu of hard limestone, sandstone, or crystalline rocks that would have to be imported.

Many gypsum products, principally hollow blocks, have also been widely used for inside walls, fireproofing, and similar work, where the strength of the material is not of prime importance and where there is no exposure to atmospheric conditions.

All of the above-mentioned forms of building material have been used in lieu of clay products.

ATTITUDE OF SOME CONTRACTORS AND BUILDERS TOWARD FLORIDA PRODUCTS

In the past, the average common and face brick supplied to Florida markets by Georgia and Alabama producers have been of superior quality to those produced by some local manufacturers. This condition, augmented by the propaganda advanced by local dealers emphasizing the higher quality of Georgia brick, in order to justify higher prices for them, has resulted in a prejudice against local products. Many architects, contractors and builders have been influenced by this sentiment and have insisted upon Georgia or Alabama products. Many of the local brick-makers are responsible for this attitude toward local brick in that they have taken little care or pride in the manufacture of their ware and have been content to supply a product of decided inferior quality. Some producers have made and more are making common brick that can compete favorably with any of the outside products.

In this connection it is interesting to note that in a series of tests made on several Florida, Georgia and Alabama products being considered for use in the recent extension of the Capitol at Tallahassee, the Florida products were found to be superior, and were used. Local brick have also been accepted by the federal architect for use in the Post Office building at Apalachicola.

ADAPTABILITY OF FLORIDA PRODUCTS

As has been pointed out, no Florida clays known at present, are suitable for the commercial production of paving brick, sewer-pipe, and the very highest qualities of face brick. All other structural materials made from clays can be produced in the State. Many of the clays now being used for mediocre products can, with the exercise of a little care in

manufacturing, be used for products of superior quality. It is true that the best Florida clays are in the western part of the State and the greatest need for them is in the peninsula, but excellent products can be made from many of the peninsula clays.

REASONS FOR FAILURE OF MANY FLORIDA VENTURES

More than fifty abandoned brick plants or former locations of plants may be found in various parts of the State. This at once raises the question as to why so many brick-producing enterprises have presumably resulted in failure. Various reasons may be assigned for this and no one reason would apply in every case. Poor management has, no doubt, caused many of these ventures to fail, and in others a clay unsuited for brick manufacture was used. In some cases, small plants were erected to supply a small local need, and this having been satisfied, the work was discontinued. In one or two cases the limited supply of clay was exhausted, and in one other case an encroaching sand-dune buried the deposit too deep to make continued manufacture profitable. In a few cases the plants were located at too great a distance from transportation to be satisfactory.

POSSIBILITIES AND RESERVES

Probable Continued Expansion and General Development—The extensive expansion and development so noticeable in Florida during the past ten or fifteen years will undoubtedly continue for several generations. The large areas of undeveloped agricultural lands, the long growing seasons, and the mild, even climate, will continue to draw home-builders and will cause a permanent and steady increase in general commercial enterprises.

The demand for clay products, and particularly structural materials, will also continue to expand with general growth and development within the State. Common brick, face brick, hollow block, fireproofing, roofing tile, and floor tile, will be more widely used than now on account of the decreasing supply and increasing cost of lumber.

Herein, therefore, lies the greatest possibility in the development of the clay industries of this State. All of the products above enumerated can be produced from Florida clays, and, if not produced in the State, will be imported from adjoining states. Very careful treatment

will be necessary to produce first-class materials from any of the local clays and this will, of course, add to the cost of manufacture. It is very probable, however, that the increased cost of transportation from producers outside of the State will exceed the cost of careful and painstaking manufacture of local products, thus giving the local manufacturer a margin in his favor. The absence of cold weather and the abundance of pine wood (at present) for cheap fuel, are additional factors favoring local manufacture.

Extensive draininge programs are now under way in some parts of the State, and many others are being planned. This will enable many of the now swampy areas to be drained, thus opening them up to agricultural and horticultural pursuits. Drain tile will be needed for much of this work, and this likewise can be produced locally, affording an opportunity for an industry of considerable magnitude in this line.

The stoneware, terra-cotta, and higher grades of clay products, can also be utilized as the demand increases.

It is to be noted, however, that the establishment of some plants, particularly those for the production of special types of structural material, as roofing tile, etc., requires the investment of a large amount of capital. Capable manufacturers, therefore, will hesitate to risk their money in such enterprises until assured of a large and steady demand for such wares.

RESERVES

As may be seen from Chapter VIII, the clay resources and reserves of the State are varied. Some sections, as for example the region in the latitude of the Everglades, and southward, have practically no clays. Other sections have clays, but none that are of practical value in the manufacture of clay products. Still others have clays that, with very careful treatment, may be used for products of fair grade. Then, some sections have an almost unlimited supply of excellent clay. For example, Escambia and northern Santa Rosa counties have vast clay reserves suitable for structural materials of excellent grade. The St. Johns River valley, from Jacksonville to Lake George, is underlain by extensive deposits of flood-plain clays, very desirable for common structural materials.

CHAPTER XI

METHODS OF PROSPECTING FOR CLAYS

It has been pointed out that this report does not attempt to include the clay deposits of Florida that are not within a reasonable distance from transportation, and as general development continues within the State, it is very probable that many deposits of clays in close proximity to transportation will be found, that are not known at the present time. It is considered expedient, therefore, to include a few general suggestions here for those who may be interested in locating new clay deposits and determining whether or not the clay is of sufficient quantity and proper quality to warrant commercial development. The same suggestions may be followed by those desiring to determine the available supply or the clay reserves in deposits already known or worked. These suggestions are designed to fit geologic and physiographic conditions in Florida, and while in general the principles of clay prospecting are the same for any type of deposit, or in any geologic region, different criteria are to be observed and conclusions drawn in a region of sedimentary rocks and of low relief, as is the case in Florida, from those which are most important in crystalline rocks or in a mountainous area.

The presence of clay deposits may be detected in wells, in road or railway cuts, in excavations for buildings, along streams, in canals, and in cliffs or banks of lakes, or along the sea shore. It often happens that clay exposures are concealed under a mantle of sand or soil or a dense growth of underbrush. In many places the presence of the clay bed is often revealed by springs or a seepage of water, particularly where the clay stratum is overlain by a porous material, as sand or soil. In some cases clay beds may be determined by the character of the vegetation growing on the surface. In the absence of natural outcrops or exposures in wells, etc., the presence of clay beds must be determined by borings, which can be done best with a small auger, described on page 253.

A few preliminary tests should be made upon the clay to determine whether or not it is even worth while to prospect the deposit in detail. Tests of this character are of little importance in indicating the real value of the clay, but, at the same time, the results may be negative and show the clay is not suited for use in manufactured products.

and, therefore, any expenditure of time or money in investigating the deposits is useless. These tests are of no value if the clay is being considered for Portland cement manufacture.

These tests are simple and easily applied, but the results must be interpreted with caution. For example, a relatively non-plastic clay may be satisfactorily worked in a dry-press machine, or it may be possible to add quantities of other plastic clays, thus making a blend which has sufficient plasticity to be worked by the stiff-mud process.

The plasticity of the clay may be judged by taking a small moist lump and working it in the hands. If it can be easily molded into various shapes which are retained without cracking as the piece is allowed to dry, the plasticity may be considered satisfactory. The presence of sand, or other gritty matter, may be easily detected by tasting a small piece of the clay. A small amount of sand or other non-plastic material is not necessarily deterimental for use in structural materials, while, in high-grade clays, such impurities as sand, etc., may be profitably removed by washing. Calcium carbonate (lime) may be detected by applying a few drops of hydrochloric acid to the clay, which will cause it to effervesce if lime is present. Calcium carbonate is detrimental, causing the product to slake after firing.

By far the safest and most satisfactory procedure is to send a clean sample of the clay, weighing about twenty or twenty-five pounds, to some ceramic laboratory making a specialty of testing clays, where the physical properties of the clay can be accurately determined and its adaptability to various uses and types of machinery can be ascertained. Many concerns manufacturing clay-working machinery make a practice of testing small samples of clay submitted by prospective purchasers of equipment, and render an opinion as to the suitability of the clay for use in the types of machinery manufactured by them. Also, arrangements may oftentimes be made with a brick manufacturer at some distance, so that he will not fear competition, whereby the clay-owner may ship a sample of clay, usually several barrels, to be tested by the manufacturer for working and burning in his plant. This method has the disadvantage that the clay to be tested may require entirely different treatment from that given the clay used at the plant where the test is being made, and, in many cases, the conclusions derived would be erroneous. High-grade clays can only be recognized by the method first listed.

After the presence of a clay deposit has been ascertained, it is next of prime importance to know its thickness and the extent of the area

which it underlies, as well as the character and thickness of the overburden or material overlying the clay. It is also desirable to know if the clay is of uniform quality throughout the deposit and, if not, the character and extent of its variation. This can best be done by means of an auger, either a "prospector's auger" or an ordinary wood auger. These should be at least two inches in diameter, and should be attached to a shaft or pipe about three-fourths of an inch in diameter. The pipe can be most conveniently handled if it is cut into lengths of about three feet each, so that as the boring increases in depth new joints may be added. A T-joint should be attached to the top so that the auger may be rotated. Borings forty or fifty feet in depth may be conveniently made with apparatus of this type.

In an area to be prospected, borings should be made about every fifty feet in each direction. A plot, or sketch map, should be made, showing the locations of the holes and an accurate record should be kept of the thickness, character and sequence of the formations encountered.

In addition to an intelligent record being kept of each hole, samples of the materials taken from the boring should be kept and properly labeled. In taking samples of borings of this type great care must be exercised so that material falling into the hole from above, or scraped off from the upper walls as the auger is withdrawn, is not included with the samples.

The samples from each boring, and particularly those from the clay stratum, should be carefully examined, in order to note any apparent changes in character, laterally or vertically, and to determine its thickness from place to place.

Samples taken by an auger are satisfactory for determining the thickness and extent of a clay deposit and any variations which may exist in it. For the determination of the physical properties of the clay, however, larger and cleaner samples are desired than is usually possible to obtain with an auger. Digging a pit is the most satisfactory method of taking a clay sample. A sample of any size desired can then be obtained and a detailed inspection of the deposit made. For a large deposit several pits should be dug.

The location of a clay deposit, with respect to transportation, markets, fuel, etc., should be given very careful consideration. A clay suitable only for structural materials would be of little value unless located very near a line of transportation and where there is an ample supply of fuel.

APPENDIX A

STATISTICS OF PRODUCTION OF BRICK IN FLORIDA, 1899 TO 1922

Year.	*Quantity. (Thousands)*	*Value.*	*Average price per thousand.*
1922	26,296	$201,684.00	$ 7.67
1921	20,163	164,395.00	8.15
1920	21,199	312,150.00	14.73
1919	16,067	185,135.00	11.52
1918	17,681	157,314.00	8.56
1917	28,457	222,227.00	7.63
1916	31,029	188,357.00	6.07
1915	31,019	182,149.00	5.87
1914	41,937	230,809.00	5.50
1913	42,450	240,126.00	5.66
1912	44,710	262,766.00	5.88
1911	36,207	216,365.00	5.98
1910	42,195	234,524.00	5.56
1909	46,272	289,016.00	6.25
1908	38,559	225,441.00	5.85
1907	51,779	343,704.00	6.64
1906	42,635	285,224.00	6.69
1905	55,242	326,929.00	5.92
1904	44,484	248,579.00	5.59
1903	36,529	218,086.00	5.94
1902	31,711	170,852.00	5.39
1901	32,253	185,759.00	5.76
1900	26,270	136,779.00	5.21
1899	26,089	132,123.00	5.06

APPENDIX B

FUSION POINTS OF SEGER CONES

Cone No.	Chemical Composition			Temperature °F	Temperature °C	Appearance of Heat
022	0.5 Na_2O 0.5 PbO	....	2 SiO_2 1 B_2O_3	1094	590	
021	0.5 Na_2O 0.5 PbO	0.1 Al_2O_3	2.2 SiO_2 1 B_2O_3	1148	620	
020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1 B_2O_3	1202	650	
019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1 B_2O_3	1256	680	
018	0.5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1 B_2O_3	1310	710	Dull Red Heat.
017	0.5 Na_2O 0.5 PbO	0.5 Al_2O_3	3 SiO_2 1 B_2O_3	1364	740	
016	0.5 Na_2O 0.5 PbO	0.55 Al_2O_3	3 SiO_2 1 B_2O_3	1418	770	
015	0.5 Na_2O 0.5 PbO	0.6 Al_2O_3	3.2 SiO_2 1 B_2O_3	1472	800	
014	0.5 Na_2O 0.5 PbO	0.65 Al_2O_3	3.3 SiO_2 1 B_2O_3	1526	830	
013	0.5 Na_2O 0.5 PbO	0.7 Al_2O_3	3.4 SiO_2 1 B_2O_3	1580	860	
012	0.5 Na_2O 0.5 PbO	0.75 Al_2O_3	3.5 SiO_2 1 B_2O_3	1634	890	Cherry Red Heat.
011	0.5 Na_2O 0.5 PbO	0.8 Al_2O_3	3.6 SiO_2 1 B_2O_3	1688	920	
010	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.50 SiO_2 0.45 B_2O_3	1742	950	
09	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.55 SiO_2 0.50 B_2O_3	1778	970	
08	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.60 SiO_2 0.40 B_2O_3	1814	990	
07	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.65 SiO_2 0.35 B_2O_3	1850	1010	Clear Cherry Red Heat.
06	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.70 SiO_2 0.30 B_2O_3	1886	1030	
05	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.75 SiO_2 0.25 B_2O_3	1922	1050	
04	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.80 SiO_2 0.20 B_2O_3	1958	1070	
03	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.85 SiO_2 0.15 B_2O_3	1994	1090	
02	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.90 SiO_2 0.10 B_2O_3	2030	1110	
01	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	3.95 SiO_2 0.05 B_2O_3	2066	1130	

FUSION POINTS OF SEGER CONES—CONTINUED

Cone No.	*Chemical Composition*			*Temperature °F*	*Temperature °C*	*Appearance of Heat*
1	0.3 K_2O 0.7 CaO	0.2 Fe_2O_3 0.3 Al_2O_3	4 SiO_2	2102	1150	Deep Orange Heat.
2	0.3 K_2O 0.7 CaO	0.1 Fe_2O_3 0.4 Al_2O_3	4 SiO_2	2138	1170	
3	0.3 K_2O 0.7 CaO	0.05 Fe_2O_3 0.45 Al_2O_3	4 SiO_2	2174	1190	
4	0.3 K_2O 0.7 CaO	0.5 Al_2O_3	4 SiO_2	2210	1210	
5	0.3 K_2O 0.7 CaO	0.5 Al_2O_3	5 SiO_2	2246	1230	
6	0.3 K_2O 0.7 CaO	0.6 Al_2O_3	6 SiO_2	2282	1250	
7	0.3 K_2O 0.7 CaO	0.7 Al_2O_3	7 SiO_2	2318	1270	
8	0.3 K_2O 0.7 CaO	0.8 Al_2O_3	8 SiO_2	2354	1290	
9	0.3 K_2O 0.7 CaO	0.9 Al_2O_3	9 SiO_2	2390	1310	White Heat.
10	0.3 K_2O 0.7 CaO	1.0 Al_2O_3	10 SiO_2	2426	1330	
11	0,3 K_2O 0.7 CaO	1.2 Al_2O_3	12 SiO_2	2462	1350	
12	0.3 K_2O 0.7 CaO	1.4 Al_2O_3	14 SiO_2	2498	1370	
13	0.3 K_2O 0.7 CaO	1.6 Al_2O_3	16 SiO_2	2534	1390	
14	0.3 K_2O 0.7 CaO	1.8 Al_2O_3	18 SiO_2	2570	1410	Bright White Heat.
15	0.3 K_2O 0.7 CaO	2.1 Al_2O_3	21 SiO_2	2606	1430	
16	0.3 K_2O 0.7 CaO	2.4 Al_2O_3	24 SiO_2	2642	1450	
17	0.3 K_2O 0.7 CaO	2.7 Al_2O_3	27 SiO_2	2678	1470	
18	0.3 K_2O 0.7 CaO	3.1 Al_2O_3	31 SiO_2	2714	1490	
19	0.3 K_2O 0.7 CaO	3.5 Al_2O_3	35 SiO_2	2750	1510	Dazzling White Heat.
20	0.3 K_2O 0.7 CaO	3.9 Al_2O_3	39 SiO_2	2786	1530	
21	0.3 K_2O 0.7 CaO	4.4 Al_2O_3	44 SiO_2	2822	1550	
22	0.3 K_2O 0.7 CaO	4.9 Al_2O_3	49 SiO_2	2858	1570	
23	0.3 K_2O 0.7 CaO	5.4 Al_2O_3	54 SiO_2	2894	1590	
24	0.3 K_2O 0.7 CaO	6.0 Al_2O_3	60 SiO_2	2930	1610	

FUSION POINTS OF SEGER CONES—Continued

Cone No.	*Chemical Composition*				*Temperature °F*	*Temperature °C*	*Appearance of Heat*
25	0.3 K_2O 0.7 CaO	6.6	Al_2O_3	66 SiO_2	2966	1630	
26[1]	0.3 K_2O 0.7 CaO	7.2	Al_2O_3	72 SiO_2	3002	1650	
27	0.3 K_2O 0.7 CaO	20	Al_2O_3	200 SiO_2	3038	1670	
28			Al_2O_3	10 SiO_2	3074	1690	
29			Al_2O_3	8 SiO_2	3110	1710	
30			Al_2O_3	6 SiO_2	3146	1730	
31			Al_2O_3	5 SiO_2	3182	1750	
32			Al_2O_3	4 SiO_2	3218	1770	
33			Al_2O_3	3 SiO_2	3254	1790	
34			Al_2O_3	2.5 SiO_2	3290	1810	
35			Al_2O_3	2 SiO_2 [1]	3326	1830	
36			Al_2O_3	2 SiO_2 [2]	3362	1850	
37			Al_2O_3	1.66 SiO_2	3398	1870	
38			Al_2O_3	1.33 SiO_2	3434	1890	
39			Al_2O_3	1 SiO_2	3470	1910	
40			Al_2O_3	0.66 SiO_2	3506	1930	
41			Al_2O_3	0.33 SiO_2	3542	1950	
42			Al_2O_3		3578	1970	

[1]Kaolin. [2]Clay Schist.

APPENDIX C

DIRECTORY OF FLORIDA CLAY WORKERS

(EXCLUSIVE OF FULLER'S EARTH)

Allentown Consolidated School,
(near) Milton, Santa Rosa County.
Temporary producers of Common Brick.

Barrineau Bros. Brick Company,
Quintette, Escambia County.
Manufacturers of Face and Common Brick and Turpentine Cups.

Callahan Brick and Tile Company,
Callahan, Nassau County.
Manufacturers of Face and Common Brick.

Campville Brick Company,
Campville, Alachua County.
Manufacturers of Common Brick.

Clay County Steam Brick Company,
Green Cove Springs, Clay County.
Manufacturers of Common Brick.

Dolores Brick Company,
Molino, Escambia County.
Manufacturers of Face and Common Brick.

Edgar Plastic Kaolin Company,
Edgar, Putnam County.
Producers of Refined Sedimentary Kaolin.

Florida China Clay Company,
Okahumpka, Lake County.
Producers of Refined Sedimentary Kaolin.

Florida Industrial School for Boys,
Marianna, Jackson County.
Manufacturers of Common Brick.

Florida Pottery,
2430 Euclid Boulevard,
St. Petersburg, Pinellas County.
Manufacturers of Ornamental Pottery.

Gamble and Stockton Brick and Tile Company,
South Jacksonville, Duval County.
Manufacturers of Face and Common Brick and Interlocking Tile.

Glendale Brick Works,
Glendale, Walton County.
Manufacturers of Common Brick.

H. A. Graack & Son Art Pottery,
Bradentown, Manatee County.
Manufacturers of Ornamental Pottery.

Guilford Bros. Brick Company,
Blountstown, Calhoun County.
Manufacturers of Common Brick.

W. J. Hall and Son Brick Company,
Chipley, Washington County.
Manufacturers of Common Brick.

Keystone Brick Company,
Whitney, Lake County.
Manufacturers of Common Brick.

Lake County Clay Company,
Okahumpka, Lake County,
Producers of Refined Sedimentary Kaolin.

McMillan Brick Company,
Molino, Escambia County.
Manufacturers of Face and Common Brick.

Morris and Blumer Brick Company,
Brooksville, Hernando County.
Manufacturers of Common Brick.

Murphy (G. H.) Brick Company,
Argyle, Walton County.
Producers of Common Brick.

Ocklocknee Brick Company,
Lawrence, Gadsden County.
(P. O. Ocklocknee.)
Manufacturers of Common Brick.

Orlando Potteries,
Orlando, Orange County.
Manufacturers of Ornamental Pottery.

Tallahassee Pressed Brick Company,
Havana, Gadsden County.
Manufacturers of Common Brick.

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Notes the shipment of brick and fire-brick to New Orleans from Pensacola prior to 1837.

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This index does not include the names of persons and corporations mentioned in the financial statement on pages 9-13, the mineral producers on pages 15-23, the fossils in Mr. Mansfield's paper, or the counties in which no clay deposits of importance were found. All the fossils are listed by families and horizons in the folded table inserted between pages 28 and 29, and the counties are discussed in alphabetical order on pages 120-215. (See table of contents.) Names of places near which fossils or clay deposits were found are not indexed as a rule, for such references tell nothing about the places themselves. But such localities are indexed under the respective counties. Numbers in parentheses indicate indirect references.

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